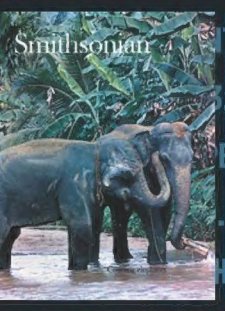

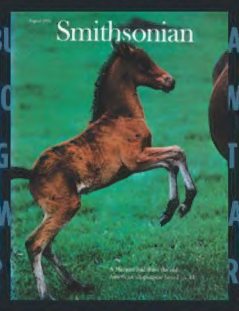
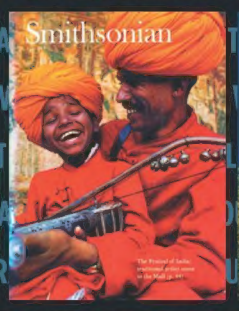

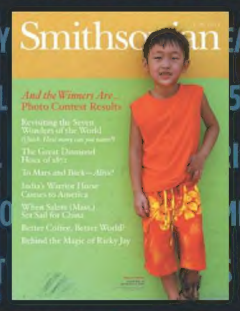

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JULY | AUGUST 2010

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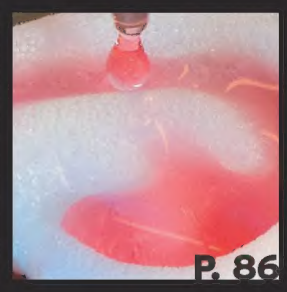
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ON THE COVER: Symbolizing changes the nation faces over the next four decades, a child observes an immigration rally in New York City. This special issue's featured luminaries include President Obama, Melinda French Gates, Sir Richard Branson and Sabiha Al Khemir.

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FROM THE EDITOR

Curveballs at the Un-Magazine

From the first issue 40 years ago, *SMITHSONIAN* has blazed its own path through the media landscape **BY CAREY WINFREY**

I DON'T BELIEVE IN GHOSTS, but I do believe the spirit of Ed Thompson, who died in 1996, still stalks these corridors, his hair slicked back, his tie loosened, a fat cigar stuck in his mouth. He swears a lot. He mumbles. Sometimes I feel him looking over my shoulder, shaking his head at what the world in general—and this magazine in particular—has come to. "What a lotta foofaw," he might say, employing a favorite expression.

Edward K. Thompson had been the editor of *Life*, back when *Life* had clout, and after *Life,* in 1968, he signed on as an assistant to the secretary of state, a job that brought him to Washington. He then came to the attention of S. Dillon Ripley, Secretary of the Smithsonian Institution, who invited Thompson to his Connecticut farm.

Thompson recalled that day in his memoir, *A Love Affair with Life & Smithsonian*: "[Ripley] started off by observing that the Institution should have had a magazine since the early 1900s—well before our times. Since I was obviously there as a possible editor, I said I didn't want to run a house organ. He said he didn't want that either. After we had rambled over some possible subject matter, we agreed that the magazine's content could be about whatever the Institution was interested in—or might be interested in. I threw in, 'And *should* be?' He agreed. That was about all that was articulated as a working idea, but an almost unlimited variety of subject matter was possible under such a concept."

Founding editor Edward K. Thompson (top) guided the new magazine through its first decade. Above from left: staff members Maran, Bonsignore, Despard, Trachtman and Foote.

In early 1969, Thompson began putting together a staff. He hired Sally Maran, who had been a reporter at *Life*, as an assistant editor. The first issue, sent to 160,000 subscribers in April 1970, featured two elephants on the cover and the line "Courting elephants." (See p. 122.) "We were very proud of it," says Maran, who retired as managing editor in 2007. "We got 30 letters on the first issue. They were 25 yeas, 3 nays and 2 that you couldn't tell."

Institution reaction was more guarded. "We had curators calling and saying, 'We have a great idea for a story on the Eastern Shore mollusk,'" Maran says. "I remember telling them, 'Well, we are going to be a *national* magazine.' And they said, 'Well, we can cover Pacific Coast mollusks in another issue.' We said, 'Thank you very much.' They were really upset that we weren't a house organ."

The director of the Natural History Museum wrote to Thompson asking that the magazine run a disclaimer disassociating its views from those of Institution scientists. Thompson hedged in his response. In a memo, the director fired back: "Many of our staff members have reacted negatively toward SMITHSONIAN, largely as a result of your response to my memorandum."

"I think we have got into an unnecessary foofaw about disclaimers," Thompson replied and suggested the two have lunch. No disclaimer ever appeared in Thompson's SMITHSONIAN.

The magazine was catching on. "Each issue of *Smithsonian* is convincing evidence that eye-popping layouts, superb

HOWARD SOCHUREK / TIME LIFE PICTURES / GETTY IMAGES; BOB PETERSON; COURTESY OF CAROLINE DESPARD; ERIC LONG, SI; BRUCE MCINTOSH; DIANA WALKER

color photography and solid craftsmanship will always lure an audience," *Newsweek* wrote in 1973, the year SMITHSONIAN first turned a profit. By then, circulation had reached 465,000; it would hit a million two years later.

"Thompson's brilliance was as a picture editor," says Joseph Bonsignore, SMITHSONIAN's longtime publisher, now retired. "The pictures were played big as they could be. The best picture went on the cover. The second-best picture went in the centerfold. In each story, the best picture led the story."

Coming up with great photographs was the job of Caroline Despard, who felt like Caroline Desperate. "I was always scared to death, because Ed Thompson was so demanding, and not always in a rational way," she recalls. "He loved issuing impossible dictums. Once he asked me for a photograph of 100 babies all in one picture. I became very fond of him, but he was terrifying to work for."

"There was a simple rule," says Paul Trachtman, an editor from 1978 to 1991 and a contributor still. "Something had to be happening. There were places that editors thought were interesting and Thompson always said, 'What's happening?' And if you couldn't answer that question, you couldn't assign the story."

"He looked like a hog butcher, but he was one of the few geniuses I've ever been close to in my life," says Timothy Foote, who had known Thompson at *Life* and joined SMITHSONIAN for a 17-year stint as an editor in 1982. "It's because of him that the whole thing worked."

In his 20 years as editor, Don Moser (top) took the circulation to two million. Above from left: staffers Wiley, Bond, Doherty and writer Conniff.

Edwards Park, an editor, wrote about his boss for the tenth anniversary issue: "[Thompson] smiles puckishly when pleased and glowers stormily when not. His office memos are collectors' items. To one staff member after a dismal showing: 'Your colleagues are aghast at your performance. You say it will improve. We await.'"

After ten years, Thompson handed the editorial reins to Don Moser, his deputy and a former *Life* colleague. Moser "pushed for higher-quality writing, better storytelling, writers who know how to 'let the camera run,'" Jack Wiley, an editor under Moser, would later recall. "The aim always was to surprise the readers; present them with a story they had seen nowhere else and were unlikely to see in the future."

"I brought in some new writers," says Moser. "I pushed a little more to do some food-related stories and sports stories. But there was no big change, because [Thompson and I] both came from the same place and pretty much saw eye to eye on what ought to be in the magazine. I always felt that you have to give people what they expect. They expect history. They expect nature. They expect science. And then you've got to throw some curveballs at them."

"Writers were always asking Don what he was looking for," says Connie Bond, an editor for 19 years. "He would say to them: 'That is your job to figure out.' How could he tell you what he wanted when he wanted you to surprise him with something he hadn't seen a hundred times before? He would say, 'Get acquainted with the magazine yourself and then surprise me.'"

"We thought of ourselves as the un-magazine," recalls Jim Doherty, also an editor for 19 years, beginning in 1983. "We prided ourselves on our singularity. We had a niche—and we were the only one in it. We refused to join the herd, chase celebrities, report trends, do what other magazines did. Our copy went on and on, often taking detours from the main narrative to explore esoteric and sometimes quite complex matters. And any subject was fair game, from square dancing to truck stops, from sports to music to education to ballet to art to science, you name it. We did not follow the pack. We followed our instincts—and our noses."

Moser doubled Thompson's decade-long tenure and took the circulation to two million, where it remains today.

Richard Conniff has contributed to the magazine for 28 years, including this issue (see "Meet the Species," p. 50). In 1997, three articles Conniff wrote about moths, giant squid and dragonflies won a National Magazine Award in the Special Interests category. "The thing that was great about the magazine, and still is," says Conniff, "is that it has a breadth of interest and a curiosity about the world." Some years ago he proposed a story to an editor at another magazine about a new event in Chicago—a poetry slam. To which, Conniff says, the editor replied: "'The *bleep* in the street doesn't give a *bleep* about a *bleeping* poetry slam.' So I took the idea to Doherty at SMITHSONIAN, who said, 'Sure, go for it.' The story we did helped turn the poetry slam into a national event."

Conniff says SMITHSONIAN's basic premise remains unchanged: "I still think there's the same editorial curiosity about the world, the same willingness to take on subjects that are quirky and revealing in small ways or large—that's still what the magazine is all about."

Reading Conniff's words, I can't help but smile and stand a little taller. Then I hear a mumbly voice in my ear: "What a lotta foofaw. Get back to work." Right, Chief.

BONNIE STUTSKI; CHAD SLATTERY; COURTESY OF CONNIE BOND; DOUG BALLOU; CLARE CONNIFF

LETTERS

JEANNE-CLAUDE'S ROLE

THE ARTICLE "California Dreamin' " [June 2010] erred in omitting artist Jeanne-Claude's essential role in the creation of the artwork *Running Fence, Sonoma and Marin Counties, California, 1972-76*. She was an equal partner with her husband, Christo, in creating the dazzling public artworks for which the couple is justly world-renowned. Jeanne-Claude's role is commemorated in the title of our current exhibition, "Christo and Jeanne-Claude: Remembering the *Running Fence*." She was deeply involved with all aspects of our exhibition before her death on November 18, 2009. The exhibition, catalog and a new documentary film commissioned by the Smithsonian American Art Museum are dedicated to her memory.

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WASHINGTON, D.C.

TODAY'S PROHIBITION

DANIEL OKRENT'S account of alcohol prohibition ["The Man Who Turned Off the Taps," May 2010] is very instructive and relevant to our current marijuana prohibition and the failed war on drugs. The nation realized the idiocy of alcohol prohibition after 13 years and repealed the constitutional amendment, but the idiocy of the present prohibition on marijuana has persisted for decades. This policy has resulted in marijuana arrests totaling at least half of all drug arrests and thousands of people being incarcerated for "nonviolent" drug crimes. Hundreds of people have been killed in Mexican cartels' drug-related violence. The United States must come to its senses: legalize, tax and regulate marijuana. The revenue could be used to treat people who have serious substance abuse problems with drugs, alcohol and tobacco.

EDWIN L. STICKNEY, M.D.
BILLINGS, MONTANA

CORRECTION:

The photograph of a New York City speakeasy ["The Man Who Turned Off the Taps"] was taken in 1933 by Margaret Bourke-White when she worked for *Fortune* magazine, not *Life*, as stated in the caption.

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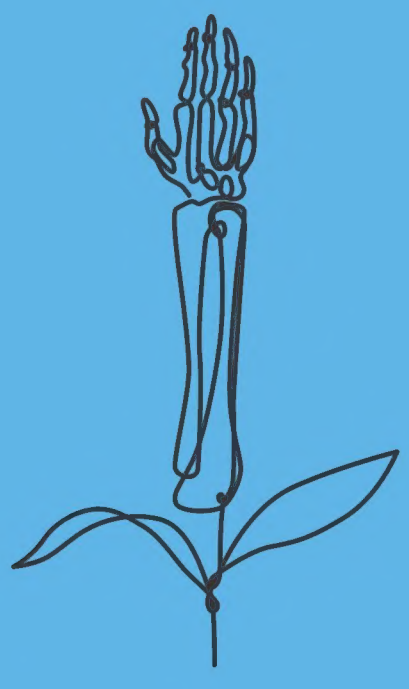

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WILD THINGS

LIFE AS WE KNOW IT

BY T. A. FRAIL, MEGAN GAMBINO, LAURA HELMUTH, ERICA R. HENDRY AND ABIGAIL TUCKER

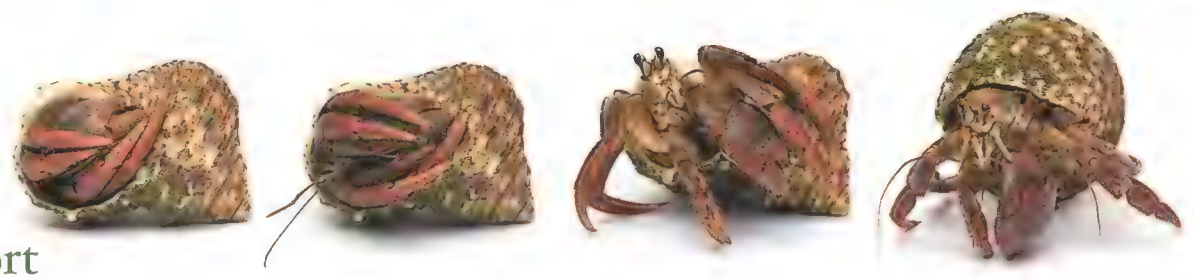
DINNER BEGINS WITH A THWACK

Scientists suspected that the common thresher shark used its long tail to capture food—and now they have video to prove it. Researchers working off the coast of Southern California with an underwater camera recorded 29 shark strikes. In the 19 successful strikes, a shark swung the upper part of its caudal fin to hit and stun a fish, immobilizing its prey before digging in to eat.

Watch the thresher shark at Smithsonian.com/WildThings

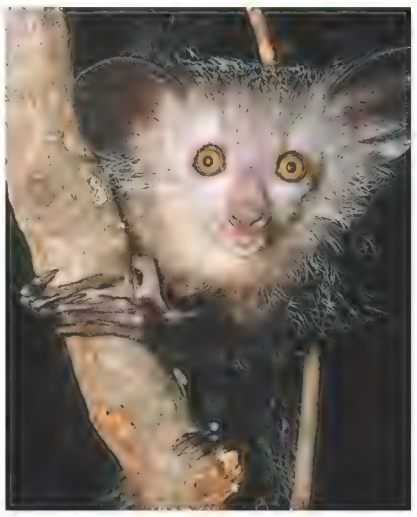
SHELL SWAP MEET

Hermit crabs that have outgrown their snail shells synchronize their search for new housing. Researchers in Belize report when one crab finds an empty shell, it waits until a crowd forms, then the crabs "piggyback," or climb onto one another's shells, in a line from largest to smallest. Once one crab shimmies into the free shell, the others follow, like dominoes.



ANATOMY OF INTIMIDATION

Cobras raise their heads when threatened and spread their hoods. To trace the patterns of muscle activation that allow this distinctive and startling behavior, scientists at the University of Massachusetts and elsewhere inserted electrodes into cobra muscles. High-speed video then documented that one set of muscles lifts the hood; a second keeps the skin taut; and a third aligns the hood's ribs.



SAFE DIGITS

Aye-ayes, a kind of lemur, have long, skinny fingers that seize grubs squirming beneath tree bark. How do they protect their delicate digits, particularly when climbing down trees headfirst? By shifting weight to their palms and curling their fingers away from the tree, says Tracy Kivell of Germany's Max Planck Institute for Evolutionary Anthropology. "It's the reverse of knuckle-walking."

Observed

NAME: The field cricket *Teleogryllus oceanicus*.
SOME SING Males attract females by rubbing their forewings together to chirp. Males who can't or don't "sing" lurk near singers to mate with lured females.
WHO LISTENS? Females do, for sure—but so do juvenile males, note biologists at the University of California at Riverside.
WHAT HAPPENS? Males who grow up amid lots of singers tend to have bigger testes than those who don't. They're in better physical condition and more likely to sing. The study shows that insects' behavior and bodies are keenly attuned to their social environments.

FRANCO BANFI / PHOTOLIBRARY; MARK BOWLER / NPL / MINDEN PICTURES (4); DAVID HARING / PHOTOLIBRARY (CAPTIVE); MARTIN HARVEY / PHOTOLIBRARY (CAPTIVE); NATHAN BAILEY

Unmasked

The 1970 photograph became an instant Earth Day classic, but its subject has remained nameless—until now **BY TIMOTHY DUMAS**

ON THE FIRST Earth Day, April 22, 1970, a mood of boisterous celebration filled the particulate-dense air of New York City. Mayor John V. Lindsay traveled around by electric bus. In a speech at Union Square he asked, "Do we want to live or die?" A crowd of 20,000 packed the square to catch a glimpse of Paul Newman standing on a raised platform. Stretches of Fifth Avenue and 14th Street, closed to automobile traffic, were transformed into pedestrian seas, amid which office workers set down picnic blankets and girls handed out fresh daisies. Activists hauled nets of dead fish through Midtown streets. "You're next, people!" they cried. "You're next!"

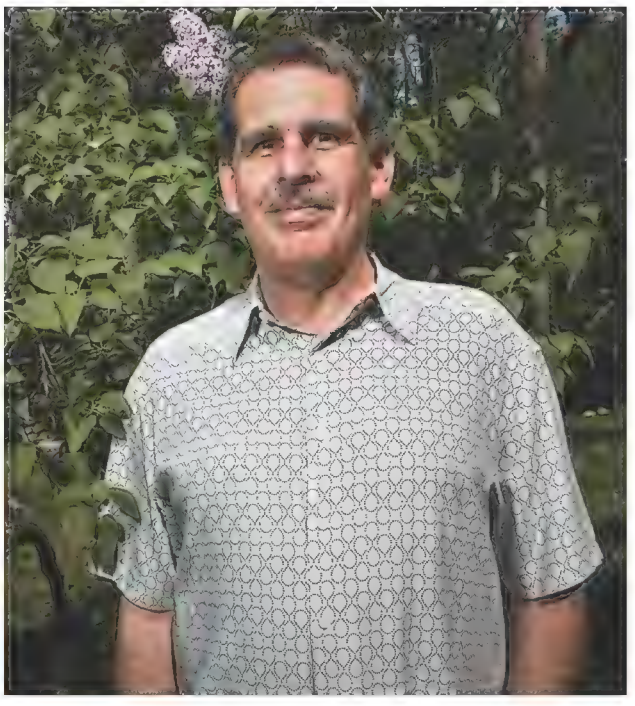
Out of all the hubbub that beset the nation that day 40 years ago—a day when students buried trash-filled caskets and put a Chevy on trial for polluting the air—one image would capture the spirit with particular efficiency and wit. It's a black-and-white photograph of a young man wearing a vintage gas mask as he stretched to smell the magnolias. Reproduced instantly and ever since, it came to symbolize the occasion. (This magazine, which made its debut in April 1970, published the picture in its 20th-anniversary issue.)

But the photograph presents a few substantial mysteries. For one, there's no record of who took it. The credit line reads simply "Associated Press," and the AP's files identify the photographer only as a "stringer," or freelancer. For another, though a few newspapers printed the young man's name with the picture at the time, he too was soon rendered anonymous.

So who was that masked man?

A long-anonymous college student in New York City reflected both the gravity and zaniness of that first Earth Day protest.

"We figured we'd at least get noticed," he says. "Whether it would be reported was something else."



Peter Hallerman (left: on Long Island Sound, c. 1972; right: in South Salem, New York, May 2010) says he still wonders why the gas mask photograph struck such a chord.

Now it can be told, or retold: his name, resurrected from a Pace College publication dated 1970, is Peter Hallerman. He was then a sophomore at Pace, commuting to its Lower Manhattan campus from Queens. In all these years, he says, he has never been interviewed about the event in question.

As he recalls, he was one of about 30 Pace students who held what was surely one of the day's puniest demonstrations. They crossed the street from their campus to a park near City Hall and chanted slogans and waved brooms, some of them daring to make a sweep or two. (Their permit forbade them to actually clean the park.)

At least the collegians had planned for maximum impact: they demonstrated at lunch hour, hoping the City Hall press corps would straggle out to gather a bit of Earth Day color. "We figured we'd at least get noticed," Hallerman says. "Whether it would be reported on was something else."

Sure enough, a handful of journalists appeared. In a dramatic flourish, Hallerman strapped on a gas mask that he believes his mother, Edith, had saved from her service with the Red Cross during World War II. (Though gas masks were a common Earth Day accessory, this long-snouted beast looked particularly awful.) The AP photographer posed Hallerman in front of a blossoming magnolia tree, then changed his mind. "Try leaning over and smelling those flowers," Hallerman recalls the photographer saying. Hallerman bent his six-foot frame over a short fence surrounding the tree so that the mask's proboscis touched the pink-white blossoms. The photographer snapped his shot, and Hallerman thought nothing more of it.

The following week, a Pace administrator presented him with an inch-thick stack of newspaper clippings that included the picture: clearly, it had struck a nerve around the country.

Peter Hallerman wasn't your standard hippie activist. In 1967 he paraded down Fifth Avenue in support of the Vietnam War. In 1969 he followed the music to Woodstock but remained ignorant of the intricacies of igniting hashish. His status as Earth Day poster boy, however, seems just: "The desire to get out, to camp, to have contact with my environment beyond the city streets, was always very strong for me," says Hallerman, a former Boy Scout and still an intrepid camper.

Hallerman's 19th birthday was on May 4, less than two weeks after that inaugural Earth Day. That was the day Ohio National Guardsmen opened fire on protesters at Kent State University, killing four and wounding nine. Four days later, Hallerman attended his first antiwar demonstration, in New York's financial district; he remembers standing on the steps of the Federal Hall National Memorial when hundreds of construction workers from the World Trade Center building site poured onto the scene, attacking the youthful protesters before storming City Hall in what came to be known as the Hard Hat Riot.

And then his witness-to-history days were over. "My wife, Ellen, jokes that I went through a mini-Forrest Gump phase," he says.

Rather than return to Pace in the fall of 1970, Hallerman drifted out West, working in coal mines and on railroad crews—fulfilling a high-school guidance counselor's judgment that he was "uniquely qualified for manual labor." After six grueling years, he headed back East and into the white-collar world. Now he's an account executive for Trans World Marketing Corporation of East Rutherford, New Jersey, which designs and makes retail displays, and he lives with his wife on a quiet, leafy lane in South Salem, New York, 50 miles north of the city.

A few years ago, Ellen and their two sons, Ethan and Matthew, now 24 and 21, gave him a mounted blowup of the famous picture for his birthday. But he hasn't hung it. Even now, he says he's surprised that it became a cultural touchstone. "I'm flattered to have been involved in something of such historic significance," he says. "But if that was my 15 minutes of fame, it's a little frustrating that I was wearing a gas mask and looked like an anteater."

TIMOTHY DUMAS *wrote the August 2009 Indelible Images, about a photograph taken at the Woodstock music festival in 1969.*

PETER HALLERMAN COLLECTION; CHRISTOPHER FARBER; PP. 8-9 AP IMAGES

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READER CONTRIBUTIONS TO OUR WEB SITE

HISTORIC CHOICES

For the magazine's 40th anniversary, Smithsonian.com asked readers to list the five most important historic events of the past 40 years. Below, in order of votes, are the events most often cited by the first 100 readers who rose to the challenge, with selected comments.

1. THE INTERNET "The internet has not only changed the way we research things, but for better or for worse has created a society of low-attention-span human beings."
—Laura Sivadle, St. Cloud, Florida

2. SEPTEMBER 11 The day is "forever ingrained in the national and global psyche, and the events of that day continue to impact our lives."
—Donna Vinson, Waianae, Hawaii

3. FALL OF THE BERLIN WALL It "indicated the world can change, and that is hopeful in our current times." —Toni Nelson, Wimberley, Texas

4. BARACK OBAMA'S ELECTION "Another nail in the coffin of narrow-mindedness and a breath of fresh air." —Nan Roche, College Park, Maryland

5. PERSONAL COMPUTER "It was never imagined that everybody could afford their own, let alone take it with them wherever they go."
—Molly Sabatino, Geneva, Illinois

To share your list, go to Smithsonian.com/top5

POP QUESTIONS

We asked visitors to the National Mall in Washington, D.C. how they felt about the future and what contemporary items they would expect to find in Smithsonian museums in 2050. Here's what some of them said:

"Many of the problems we're very concerned about will be dealt with through technology. In the 18th century, predictions of starvation and famine were completely wrong because of technology that came along."
—**Scott Berridge,** Washington, D.C.

"In 30 to 40 years, cars may be obsolete, because everyone will hit a button and [their vehicles] will fly. And just as with the GPS, you'll be able to put in where you're going and there'll be a place where you can land."
—**Rudolph Smith,** Baltimore, Maryland

"I have great faith in this country and in this world and I believe that people will find solutions and figure out how to move forward collectively."
—**Susan Cummins,** Bethesda, Maryland

To see video interviews, go to Smithsonian.com/malltalk

PHOTO CONTEST
EDITORS' PICK

"The architectural feature that attracted me was this red luminous panel in a corridor. The idea of creating a silhouette popped into my head. After several minutes a young man walked by, and I seized the opportunity."
—**Paulo Nunes dos Santos,** of Dublin, Ireland, on his photograph taken at the Hong Kong International Airport

Enter your photograph at Smithsonian.com/photocontest

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Around the Mall

SCENES AND SIGHTINGS FROM THE SMITHSONIAN MUSEUMS AND BEYOND

KATJA HEINEMANN / AURORA SELECT

OLD IS NEW

AN MIT PROFESSOR SHOWS HOW ANCIENT ARCHITECTURE CAN BE THE BASIS FOR A MORE SUSTAINABLE FUTURE

PAGE 18

From the Castle p. 16
Q&A: Nina Simon p. 20
What's Up p. 22

"Sometimes simpler technology is the most sophisticated or most appropriate," says John Ochsendorf.

Forward Thinking

BY G. WAYNE CLOUGH

S. DILLON RIPLEY, Secretary of the Smithsonian from 1964 to 1984, created eight new museums, a Folklife Festival on the National Mall—and, 40 years ago, this magazine. Today, as we look forward to the next 40 years, we believe we are entering another era of expansion—particularly on the Web. Last year there were 30 million visits to Smithsonian museums, but there were more than six times that number to our Web sites. With an estimated 1.7 billion Web users in a global population of 6.8 billion, the Smithsonian's digital future is only beginning. Imagine a world where our 136.9 million artifacts, specimens and works of art are captured in stunning 3-D digital images that virtual visitors bring into their homes. Smithsonian scientists and other scholars, appearing as lifelike holograms, will tell stories and answer questions about each image. Intuitive, interactive search mechanisms will quickly guide individuals through our collections based on their personal interests and word associations.

Secretary S. Dillon Ripley (on his farm in 1984) enjoyed diffusing knowledge.

By 2050, online visitors will in effect be stepping back to the future, since in 1881 all of the Smithsonian's collections were together in what was then called the U.S. National Museum. Visitors saw displays about art, science, culture and history—all in close proximity. So, too, in the virtual Smithsonian, where Web visitors will be able to instantly browse our vast and varied collections. One of our Strategic Plan's grand challenges is increasing understanding of the diverse American experience. Future Web visitors will be able to interact with our collections from the perspectives of different ethnic groups. Still, in-person museum visits will always be special in their own way—there is no way a virtual visit could ever supplant the thrill of touching a moon rock or standing next to the Star-Spangled Banner.

The prospects for Smithsonian research in the next 40 years are no less exciting. Discussing his new book about the Enlightenment, *The Age of Wonder: How the Romantic Generation Discovered the Beauty and Terror of Science*, biographer and historian Richard Holmes recently considered science today and in the coming decades. To my delight and surprise, he concluded: "If there is a second Age of Wonder, I believe it will be driven by the United States of America, and that the Smithsonian will be at the heart of this new possibility."

G. WAYNE CLOUGH *is Secretary of the Smithsonian Institution.*

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Vaulting Into the Future

How poor countries can build sturdy structures from inexpensive, local materials

IN A BASEMENT WORKSHOP, John Ochsendorf stands beneath a thin layer of bricks mortared into a sinuous overhead arch that seems to defy gravity. With the heel of his hand, he beats against the bricks. "Hear that ringing?" he asks. "It's tight like a drum."

Ochsendorf, 36, a Massachusetts Institute of Technology professor of civil engineering and architecture, is demonstrating why this style of arched ceiling, or vault—common in churches and other buildings throughout the Mediterranean—is named after the timbrel, an ancient musical instrument with a tightly stretched tambourine-like surface.

"Basically, 5,000 years of progress was thrown out the window," Ochsendorf says of the 600-year-old building technique (above from left: at South Africa's Mapungubwe Park; at Cooper-Hewitt).

The vault relies on the architectural principles that guided the construction of ancient Roman buildings, such as a 33-acre public bathhouse in central Rome that still stands today. The more elegant timbrel vault technology emerged in the 14th century, replacing the heavy stones favored by the Romans with terra-cotta tiles. Ochsendorf opted for 1 1/2-inch-thick bricks.

The structure is a full-scale prototype of a timbrel vault now on view at the Cooper-Hewitt, National Design Museum in New York City. *Vault201* (named for the gallery where it resides) is part of the museum's National Design Triennial—on view through January 9, 2011—held every three years to showcase innovative design. This year's theme, "Why Design Now?" celebrates projects that tackle human and environmental problems around the world.

NO. 1
ARCHITECTS WILL CONSTRUCT SOPHISTICATED MODERN BUILDINGS OUT OF MUD.

Ochsendorf hopes to prove that sturdy, eye-pleasing structures can be built inexpensively out of local materials. And by using, say, clay and mud, instead of steel and concrete, the energy consumption and pollution associated with construction projects can be significantly reduced. (Cement production alone accounts for an estimated 5 percent of all carbon dioxide emissions worldwide.) The bricks in *Vault201* were made from 100 percent recycled material—including industrial waste and raw sewage.

"John does really high-tech engineering with low-tech resources," says Cooper-Hewitt Deputy Curatorial Director Matilda McQuaid. "He has reinvigorated this 600-year-old Mediterranean building technique in a way that is stunningly beautiful today."

Historically, such vaults contained two or more layers fused together for stability, but Ochsendorf built a single layer to demonstrate the form's inherent strength. "People don't expect something that's this thin to stand," he says. In his basement workshop, he underscores the point by climbing eight feet up a ladder and stepping onto the top of the vault. Watching nervously from below are the half-dozen architecture students who helped Ochsendorf design and build the vault, along with several members of the New York-based engineering firm Robert Silman Associates, on hand to certify its structural soundness for display in the museum.

The Cooper-Hewitt exhibit also includes photographs and time-lapse video documenting the 2007 to 2010 construction of the MIT professor's most famous work, the Mapungubwe National Park Interpretive Center in South Africa. The center's soaring domes were constructed from 300,000 soil tiles made on-site by two dozen local laborers—overseen by Ochsendorf, a team of students, and an architect and an engineer, both from South Africa. Among the many benefits of this approach: a 90 percent reduction in carbon emissions over standard construction techniques. Last fall, the World Architecture Festival in Barcelona honored the center as the World Building of the Year.

Ochsendorf goes beyond "form follows function." For him, form must also follow a deeper understanding of its impact on the surrounding environment. "With the Industrial Revolution, basically 5,000 years of progress was thrown out the window," he says of the masonry vault. "People assume that in the 21st century buildings should be made of titanium, because we have a narrow definition of progress. Maybe a 21st-century building is made out of dirt used in an intelligent and beautiful way."

LOGAN WARD

ROBERT RICH, PETER RICH ARCHITECTS; KATJA HEINEMANN / AURORA SELECT

Watch video of the South African visitors center construction at Smithsonian.com/vault

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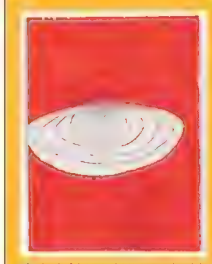

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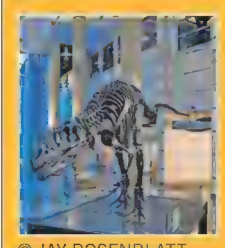

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Q&A

NINA SIMON, author of the blog Museum 2.0 and the book *The Participatory Museum*, advises museums how to involve visitors in the design of exhibitions. She spoke with the magazine's Erica R. Hendry.

You wrote your book using an online format similar to Wikipedia that allowed input from anyone who signed up. How did that turn out?
It turned out fabulously. There were lots of people—most of whom, to this day, I still haven't met—who made incredible contributions to the book. I was surprised that many of them said it didn't matter if I used their suggestions, as long as they knew I was thinking about and responding to them.

What can museums learn from your experience?
They should be confident enough to figure out the balance between "What does my audience want?" versus "What am I willing to give?" Frequently, when designing museum exhibits, you ask people for feedback. But once you're in the thick of making the thing, you don't want anybody telling you to go in another direction. The key is to create a system where you can make the most of what people have to offer, through all stages of the process, without eroding the quality of the exhibits.

Can you give me an example?
When I was working at the Tech Museum in San Jose, we invited people through the Internet to come up with ideas for exhibits, and then we picked some of the best. It is extraordinary the way that nontraditional audiences, people who don't usually come to museums, change their perspective if they are personally invited to participate.

What will a successful museum look like 40 years from now?
A successful museum will be one that people see as a community place, like the local coffee shop or the library—not a place they visit just once a year.

Read more of our interview with Nina Simon at Smithsonian.com/simon

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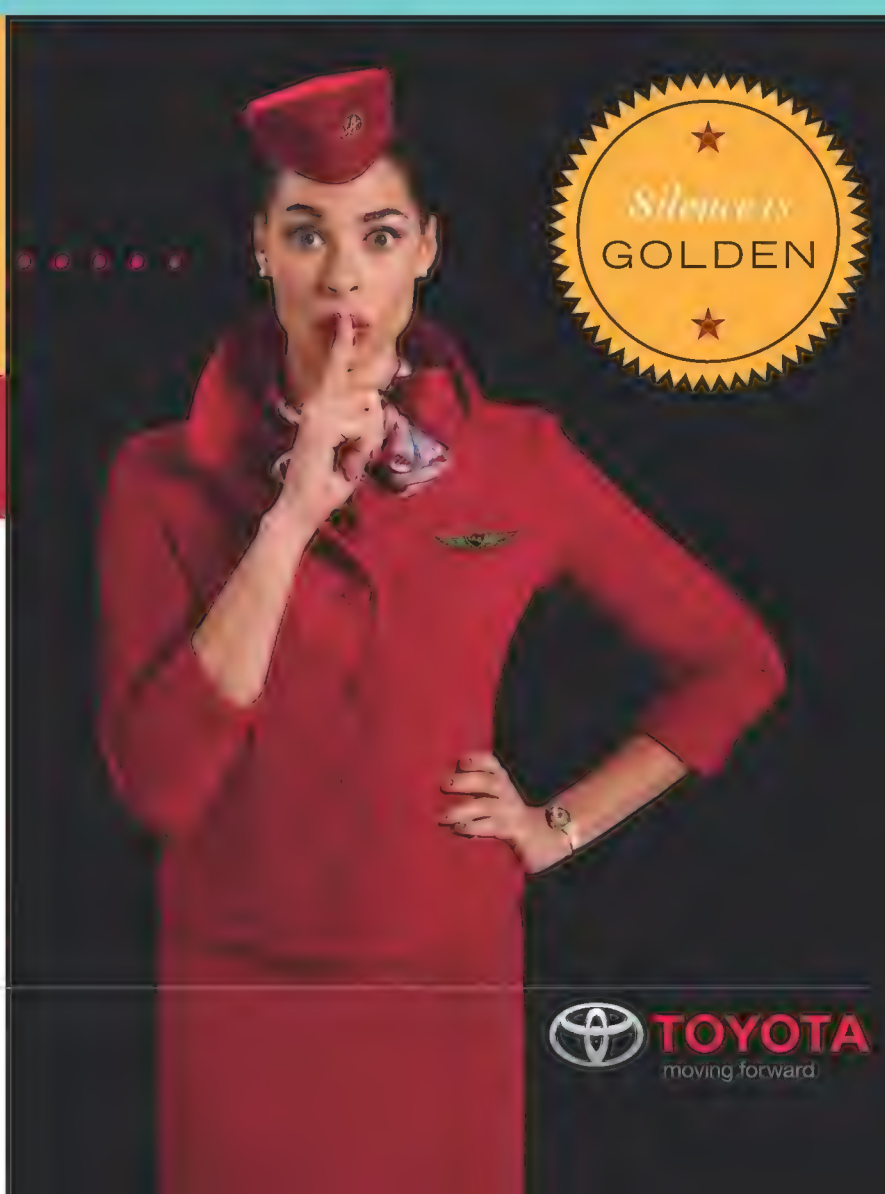


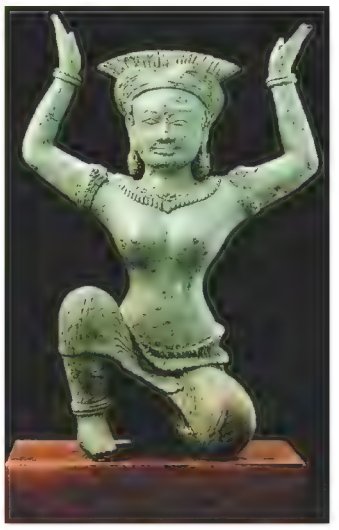
TRAVEL AVALON CLASS

Options shown. ©2010 Toyota Motor Sales, U.S.A., Inc. toyota.com/avalon

What's Up

FLEETING BEAUTY

Beginning August 14 at Natural History, see magnificent plants on the verge of extinction—such as the Peruvian orchid *Phragmipedium kovachii* (left: by Angela Mirro)—in lush illustrations by members of the American Society of Botanical Artists in "Losing Paradise: Endangered Plants Here and Around the World."



THE BRONZE AGE

The saga of ancient bronze casting in Cambodia (left: *Kneeling female figure,* 12th century A.D.) is told through a collection of 36 sculptures created by artisans spanning 1,700 years. Now at the Sackler Gallery through January 23, 2011.

CLASSIC STORIES

Filmmakers George Lucas and Steven Spielberg pay homage to a master storyteller by lending their private collections of Norman Rockwell paintings (right: *First Trip to the Beauty Shop,* 1972) to American Art for an exhibit opening July 2.

GRASS ROOTS

African slaves brought their art of basket weaving (right: wave basket, 2004) to the American South. See these "containers of memory" through November 28 at African Art.

TRUE COLORS

Starting July 1, guitarist Jimi Hendrix's patchwork coat (left) is one of several iconic items at the American Indian Museum's "Up Where We Belong: Native Musicians in Popular Culture."

BY ERICA R. HENDRY

NMNH, SI; COURTESY OF THE NATIONAL MUSEUM OF CAMBODIA, PHNOM PENH; COLLECTION OF GEORGE LUCAS, ©ROCKWELL ESTATE LICENSING / SAAM; NMAI, SI; NMAA, SI

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Get an insider's look at the Smithsonian at Smithsonian.com/mallblog

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Smithsonian
JULY | AUGUST 2010 · VOLUME 41, NUMBER 4

ANTICIPATION

We salute the basic human urge to remember the future

BY TERENCE MONMANEY

WE'RE HONORED THAT PRESIDENT BARACK OBAMA HAS contributed to this 40th anniversary issue about breakthroughs, trends and events likely to shape our world over the next 40 years. In his essay, "Why I'm Optimistic" (p. 58), he praises Americans' "enduring faith, even in the darkest hours, that brighter days lie ahead."

To get a fix on Americans' attitudes about the coming decades, we collaborated with the nonpartisan Pew Research Center on an opinion poll ("Americans Look to 2050," p. 70). Most people surveyed believed in the power of science to improve their lives, yet they expressed concern about the environment, as well as anxiety about population growth and immigration.

That anxiety isn't shared by Joel Kotkin, a journalist specializing in demography, who argues in "Ready, Set, Grow" (p. 60) that an increase of 100 million people in the United States by 2050 will be beneficial. George Friedman, a geopolitical analyst, also defies received wisdom, saying the nation's pre-eminence, far from ending, has only just begun ("The U.S. Stays on Top," p. 69).

When SMITHSONIAN debuted in 1970, the announcement said (please forgive the masculine usage) it would "probe Man's disasters, from oil spills to famine, clarify his predicaments, from overpopulation to pollution, and join battle for his improvement." And so we do. In these pages and on our Web site, Smithsonian.com, you'll learn about threats to oceans and wildlife. But you'll also learn about efforts to ease hunger, disease and poverty. "I am filled with hope," says Melinda French Gates, co-chair of the Bill & Melinda Gates Foundation ("Saving Lives," p. 84).

Scientists say the capacity to imagine the future is one of the most salient human qualities, separating us from other animals and even our fellow primates. The idea behind this special issue is to get a better feel for the consequences of what humanity is up to, and to anticipate whatever's next. SMITHSONIAN set out 40 years ago to "fashion guideposts for today and tomorrow." That pursuit seems more pressing than ever.

TERENCE MONMANEY *is the magazine's executive editor.*

THE 40 THINGS YOU NEED TO KNOW

1. SOPHISTICATED BUILDINGS WILL BE MADE OF MUD.
2. CORAL REEFS WILL BE DEVASTATED.
3. THE CATCH OF THE DAY? JELLYFISH.
4. NEW CARS WILL BE GIVEN AWAY, FREE.
5. INDUSTRY WILL GENERATE ENERGY IN SPACE.
6. OYSTERS WILL SAVE WOLVES FROM CLIMATE CHANGE.
7. 2,000 NEW MAMMAL SPECIES WILL BE DISCOVERED.
8. IT'S CURTAINS FOR THE WORLD'S RAREST DOLPHIN.
9. FARMERS WILL PLANT SPINACH IN TALL BUILDINGS.
10. THE NATION WILL MEET THE TESTS OF THE CENTURY AHEAD.
11. THE HEARTLAND WILL RISE AGAIN.
12. THE TOP U.S. SOCIAL PROBLEM? UPWARD MOBILITY.
13. BY 2050, ONE OUT OF THREE U.S. KIDS WILL BE LATINO.
14. WORLD WAR III WILL BEGIN. IN SPACE.
15. MOST AMERICANS FEAR FOR THE PLANET'S HEALTH.
16. UNLESS WE CONSERVE, MORE PEOPLE WILL GO HUNGRY.
17. AN ANCIENT GRAIN, FONIO, WILL FIGHT STARVATION.
18. AFGHANISTAN RISKS TURMOIL FOR 40 YEARS.
19. GLOWING SQUID WILL LEAD TO NEW ANTIBIOTICS.
20. HEALTH WORKERS WILL ERADICATE MALARIA.
21. SCIENCE COULD ENABLE A PERSON TO REGROW A LIMB.
22. ASTRONOMERS WILL DISCOVER LIFE BEYOND EARTH.
23. HOW WILL WE AVERT THE DINOSAURS' FATE? TELESCOPES.
24. BRAIN SCANS WILL ILLUMINATE THE INFANT MIND.
25. ARTISTS WILL RUN THE WORLD.
26. NOVELISTS WILL NEED A NEW PLOT DEVICE.
27. EVERYONE WILL MAKE HIS OWN MUSIC.
28. SECRETS WILL REVEAL IF YOUNG JFK WAS "VACUOUS."
29. JAMES CAMERON WILL STILL BE MAKING MOVIES AT 96.
30. STAND-UP COMEDY WILL NO LONGER KILL.
31. NATIVE AMERICAN YOUTHS WILL REVIVE THEIR CULTURE.
32. U.S.-MUSLIM RELATIONS WILL IMPROVE.
33. EVOLUTION WILL CONTINUE IN REVERSE, HUMORIST SAYS.
34. A MEDICAL LAB WILL FIT ON A POSTAGE STAMP.
35. VIRUSES WILL HELP BUILD MACHINES.
36. GOODBYE, STEREO; HELLO, HYPER-REAL ACOUSTICS.
37. ELECTRICITY WILL BE HARVESTED FROM YOUR SKIN.
38. CRUCIAL ENERGY WILL BE GENERATED WITH MIRRORS.
39. YOUR REFRIGERATOR WILL TALK TO YOU.
40. READING WILL BECOME AN ATHLETIC ACTIVITY.

THE ENVIRONMENT

40 THINGS TO KNOW

THE NEW KI

NG OF THE SEA

As the world's oceans are degraded, will they be dominated by jellyfish?

BY ABIGAIL TUCKER

PHOTOGRAPHS BY JOHN LEE

Jellyfish (Northeast Pacific sea nettles in the Monterey Bay Aquarium) are brainless, bloodless and mostly aimless. The animals evolved more than 500 million years ago.

ON THE NIGHT OF DECEMBER 10, 1999, THE PHILIPPINE island of Luzon, home to the capital, Manila, and some 40 million people, abruptly lost power, sparking fears that a long-rumored military coup d'état was underway. Malls full of Christmas shoppers plunged into darkness. Holiday parties ground to a halt. President Joseph Estrada, meeting with senators at the time, endured a tense ten minutes before a generator restored the lights, while the public remained in the dark until the cause of the crisis was announced, and dealt with, the next day. Disgruntled generals had not engineered the blackout. It was wrought by jellyfish. Some 50 dump trucks' worth had been sucked into the cooling pipes of a coal-fired power plant, causing a cascading power failure. "Here we are at the dawn of a new millennium, in the age of cyberspace," fumed an editorial in the *Philippine Star*, "and we are at the mercy of jellyfish."

A decade later, the predicament seems only to have worsened. All around the world, jellyfish are behaving badly—reproducing in astonishing numbers and congregating where they've supposedly never been seen before. Jellyfish have halted seafloor diamond mining off the coast of Namibia by gumming up sediment-removal systems. Jellies scarf so much food in the Caspi-

an Sea they're contributing to the commercial extinction of beluga sturgeon—the source of fine caviar. In 2007, mauve stinger jellyfish stung and asphyxiated more than 100,000 farmed salmon off the coast of Ireland as aquaculturists on a boat watched in horror. The jelly swarm reportedly was 35 feet deep and covered ten square miles.

Nightmarish accounts of "Jellyfish Gone Wild," as a 2008 National Science Foundation report called the phenomenon, stretch from the fjords of Norway to the resorts of Thailand. By clogging cooling equipment, jellies have shut down nuclear power plants in several countries; they partially disabled the aircraft carrier USS *Ronald Reagan* four years ago. In 2005, jellies struck the Philippines again, this time incapacitating 127 police officers who had waded chest-deep in seawater during a counterterrorism exercise, apparently oblivious to the more imminent threat. (Dozens were hospitalized.) This past fall, a ten-ton fishing trawler off the coast of Japan capsized and sank while hauling in a netful of 450-pound Nomura's jellies.

The sensation of getting stung ranges from a twinge to tingling to savage agony. Victims include Hudson River triathletes, Ironmen in Australia and kite surfers in Costa Rica. In summertime so many jellies mob the waters of the Mediterranean Sea that it can appear to be blistering, and many bathers' bodies don't look much different: in 2006, the Spanish Red Cross treated 19,000 stung swimmers along the Costa Brava. Contact with the deadliest type, a box jellyfish native to northern Australian waters, can stop a person's heart in three minutes. Jellyfish kill between 20 and 40 people a year in the Philippines alone.

Jellies can harm swimmers (top: Hawaii) and disrupt fishing (above: Japan).

The news media have tried out various names for this new plague: "the jellyfish typhoon," "the rise of slime," "the spineless menace." Nobody knows exactly what's behind it, but there's a queasy sense among scientists that jellyfish just might be avengers from the deep, repaying all the insults we've heaped on the world's oceans.

"JELLYFISH" IS A DECIDEDLY unscientific term—the creatures are not fish and are more rubbery than jamlike—but scientists use it all the same (though one I spoke with prefers his own coinage, "gelata"). The word "jellyfish" lumps together two groups of creatures that look similar but are unrelated. The largest group includes the bell-shaped beings that most people envision when they think of jellyfish: the so-called "true jellies" and their kin. The other group consists of comb jellies—ovoid, ghostly creatures that swim by beating their hairlike cilia and attack their prey with gluey appendages instead of stinging tentacles. (Many other gelatinous animals are often referred to as jellyfish, including the Portuguese man-of-war, a colony of stinging animals known as a siphonophore.) All told, there are some 1,500 jellyfish species: blue blubbers, bushy bottoms, fire jellies, jimbles. Cannonballs, sea walnuts. Pink meanies, a.k.a. stinging cauliflowers. Hair jellies, a.k.a. snotties. Purple people eaters.

The bell-shaped jellies—distantly related to corals and anemones—launched their lifestyle long, long ago. Exquisite jellyfish fossils found recently in Utah display reproductive organs, muscle structure and intact tentacles; the jelly fossils, the oldest discovered, date back more than 500 million years, when Utah was a shallow sea. By contrast, fish evolved only about 370 million years ago.

The descendants of those ancient jellies haven't changed much. They are boneless and bloodless. In their domelike bells, guts are squished beside gonads. The mouth doubles as an anus. (Jellies are also brainless, "so they don't have to contemplate that," one jelly specialist says.) Jellies drift at the mercy of the currents, though many also propel themselves by contracting their bells, pushing water out, while others—such as the upside-down jellyfish and the flower hat, with its psychedelic lures—can recline on the seafloor. They absorb oxygen and store it in their jelly. They can sense light and certain chemicals. They can grow quickly when there's food around and shrink when there isn't. Their tentacles, which reach up to 100 feet long in some species, are covered with cells called nematocysts that fire tiny poison harpoons, enabling the animals to immobilize krill, larval fish and other prey without risking their mushy bodies in a struggle. Yet if a sea turtle bites off a hunk, the flesh regenerates.

A breeding jellyfish can spit out unfertilized eggs at a prodigious rate: one female sea nettle may spew as many as 45,000 per day. To maximize the chances of sperm meeting egg, millions of moon jellies of both sexes assemble in one place for a gamete-swapping orgy.

Chad Widmer is one of the world's most accomplished

LUCY PEMONI / AP IMAGES; AWASHIMAURA FISHERIES ASSOCIATION / REUTERS; PP. 26-27 JOHN LEE / AURORA SELECT; ICON ILLUSTRATIONS: STEVEN NOBLE

A colleague calls Chad Widmer (at the Monterey Bay Aquarium) a true "jelly master." Widmer breeds the creatures in captivity and tests their ability to withstand conditions predicted for future oceans (top right: harbor jellies; above right: crystal jellies).

jellyfish cultivators. At the Monterey Bay Aquarium in California, he is lord of the "Drifters" exhibit, a slow-motion realm of soft edges, rippling flute music and sapphire light. His left ankle is crowded with tattoos, including Neptune's trident and a crystal jellyfish. A senior aquarist, Widmer labors to figure out how jellyfish thrive in captivity—a job that involves untangling tentacles and plucking gonads until his arm is swollen with venom.

Widmer has bred dozens of jellyfish species, including moon jellies, which resemble animated shower caps. His signature jelly is the Northeast Pacific sea nettle, displayed by the score in a 2,250-gallon exhibit tank. They are orange and incandescent, like dollops of lava, and when they swim against the current they look like glowing meteors streaming to Earth.

The waters of Monterey Bay have not been spared from the gelatinous woes said to be sweeping the oceans. "It used to be that everything had a season," Widmer says. Spring was the time for lobed comb jellies and crystal jellies to arrive. But for the past five years or so, those species seem to be materializing almost at random. The orange spotted comb jelly, which Widmer nicknamed the "Christmas jelly," no longer peaks in December; it haunts the shoreline practically year-round. Black sea nettles, once seen mostly in Mexican waters, have started appearing off Monterey. Last August, millions of Northeast Pacific sea nettles bloomed in Monterey Bay and clogged the aquarium's seawater intake screen. The nettles

JOHN LEE / AURORA SELECT (3)

"I think it's entirely possible we've made things better for the jellyfish," says Jennifer Purcell (in Bellingham, Washington).

typically retreat by early winter. "Well," Widmer informs me gravely on my February visit, "they're still out there."

IT'S HARD TO TELL what may be causing jellyfish to proliferate. The fishing industry has depleted populations of big predators such as red tuna, swordfish and sea turtles that feed on jellyfish. And when small, plankton-eating fish such as anchovies are overharvested, jellies flourish, gorging on plankton and reproducing to their hearts' content (if they had hearts, that is).

In 1982, when the Black Sea ecosystem was already weakened by anchovy overfishing, the warty comb jelly (*Mnemiopsis leidyi*) arrived; a species native to the East Coast of the United States, it was most likely carried across the Atlantic in a ship's ballast water. By 1990, there were some 900 million tons of them in the Black Sea.

Pollution, too, may be fueling the jelly frenzy. Jellyfish succeed in all sorts of fouled conditions, including "dead zones," where rivers have pumped fertilizer runoff and other materials into the ocean. The fertilizer fuels phytoplankton blooms; after the phytoplankton die, bacteria decompose them, hogging oxygen; the oxygen-depleted water then kills or forces out other marine creatures. The number of coastal dead zones has doubled every decade since the 1960s; there are now roughly 500. (Oil can kill jellyfish, but no one knows how jellyfish populations in the Gulf of Mexico will fare in the long run after the BP oil spill.)

Carbon-based air pollution may be another factor. Since the Industrial Revolution, the amount of carbon in the atmosphere from burning fossil fuels and wood as well as from other enterprises has risen by some 36 percent. That contributes to global warming, which, some researchers speculate, may benefit jellyfish at the expense of other marine animals. Moreover, carbon dioxide dissolves in seawater to form carbonic acid—a major threat to marine life. As the seas become more acidic, scientists say, ocean water will begin to dissolve animal shells, stunt coral reefs and disorient larval fish by skewing their sense of smell. Jellies, meanwhile, may not even be inconvenienced, according to recent studies by Jennifer Purcell of Western Washington University.

Purcell and a graduate student, Amanda Winans, decided to breed moon jellyfish in water with the staggering acid levels that some scientists say will prevail in the years 2100 and 2300. "We took it to very severe acid, using the worst predictions," Purcell says. The jellyfish reproduced with abandon. She has also conducted experiments that lead her to suspect that many jellies reproduce better in warmer water.

With the world's human population expected to increase 32 percent by 2050, to 9.1 billion, a number of environmental conditions that favor jellyfish are predicted to become more common. Jellyfish reproduce and move into new niches so rapidly that even within 40 years, some experts predict "regime shifts" in which jellyfish assume dominance in one marine ecosystem after another. Such shifts may have already occurred, including off Namibia, where, after years of overharvesting, the once fecund waters of the Benguela current now contain more jellyfish than fish.

Steven Haddock, a zooplankton scientist at the Monterey Bay Aquarium Research Institute (MBARI), is concerned that researchers and the news media may be overreacting to a few isolated jelly outbreaks. Not enough is known about historical jelly abundances to distinguish between natural fluctuation and long-term change, he says. Are there really more of the creatures, or are people simply more prone to notice and report them? Are the jellyfish changing, or is our perspective? A self-described "jelly hugger," Haddock worries that jellyfish are taking the blame for messing up the seas when we're the ones causing the damage. "I just wish that people had the perception that jellyfish are not the enemy here," Haddock says.

Purcell, who sports jellyfish earrings the day I meet her in Monterey, says she is disgusted by what she sees as humanity's

The loosely defined term "jellyfish" encompasses about 1,500 species, ranging in size from microscopic to more than seven feet wide and 100 feet long. Opposite clockwise from top left: purple-lipped cross jellyfish, a deep-sea species; crystal jellyfish, which live in cool waters; spotted jellyfish are tropical and have weak stingers; moon jellyfish are a common temperate species.

JOHN LEE / AURORA SELECT (5)

efforts to exploit the ocean, filling it with fish farms and oil wells and fertilizer. Compared with fish, jellies are "better feeders, better growers, more tolerant of all kinds of things," she told me, adding of the marine environment: "I think it's entirely possible we've made things better for jellyfish." Part of her likes the idea of unruly jellies causing a commotion and foiling our plans. She's cheering for them, almost.

Jellyfish fossils found recently in Utah display reproductive organs, muscle structure and tentacles.

WIDMER'S LAB AT THE MONTEREY Aquarium is dominated by bubbling lime-green columns of algae, which he feeds to brine shrimp, which he then feeds to jellyfish. The algae come in six other "flavors," but he says he prefers the green type for its mad scientist aesthetic. The room is full of jellyfish tanks ranging in size from salad bowls to wading pools. The containers rotate slowly, creating a current. "Let's feed!" Widmer cries. He scrambles up and down stepladders, squirting a turkey baster of pink krill into this tank and that.

Toward the back of the lab, haggard orange sea nettles stumble along the bottom of their tank, their bells brownish and transparent, their tentacles torn. These, Widmer says, have been taken out of the public display and retired. "Retired" is Widmer's euphemism for "about to be snipped up with fabric scissors and fed to other jellies."

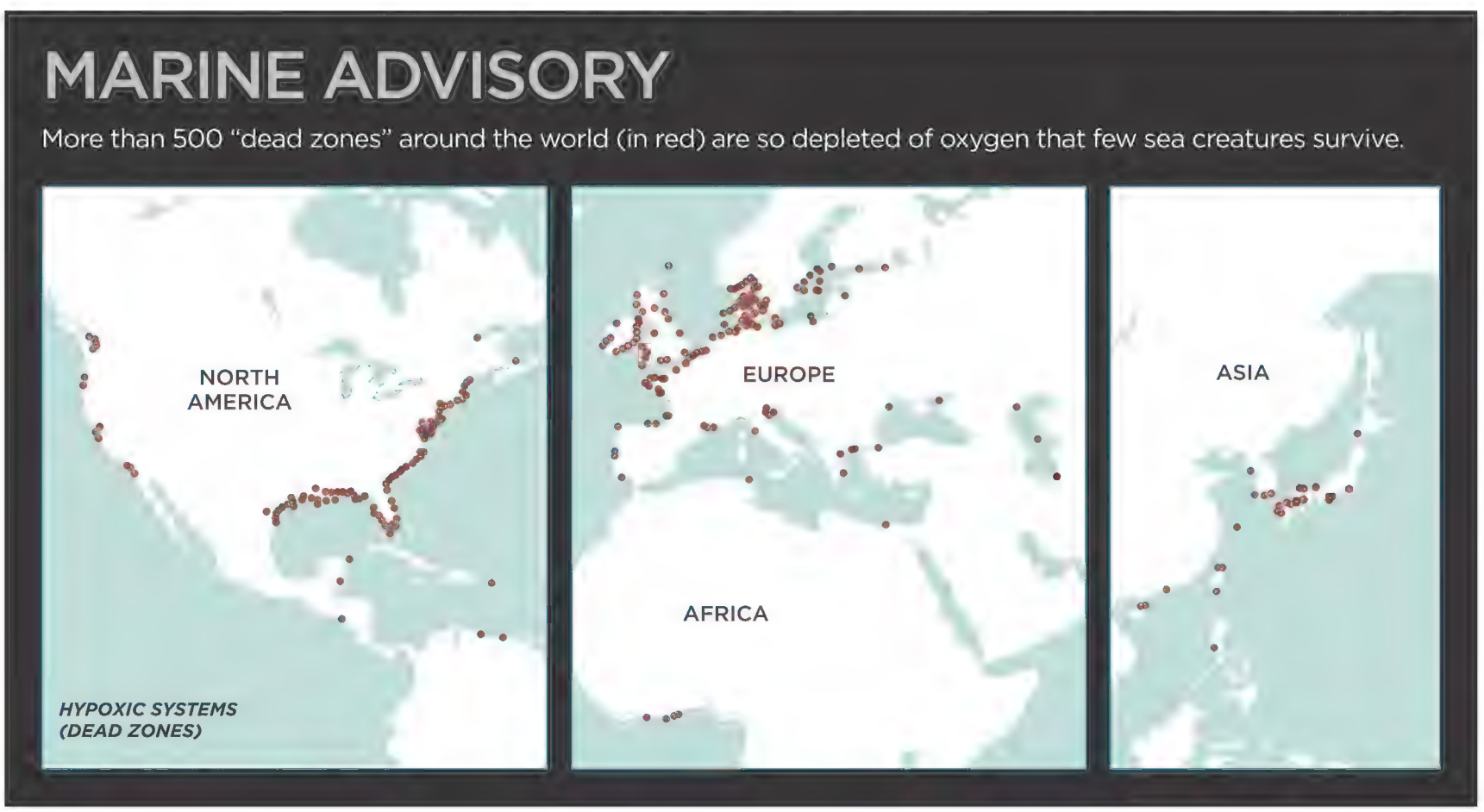
He calls his prize specimens "golden children." He speaks to them in cooing tones usually reserved for kittens. One tank holds the petite but striking purple-lipped cross jellies, which Widmer retrieved from Monterey Bay. The species has never been bred in captivity before. "Oh, aren't you cute!" he trills. The other golden child is a small brown smudge on a pane of glass. This, he explains, dabbing artistically at the smudge's edges with a paintbrush, is a colony of lion's mane jellyfish polyps.

When jellyfish sperm and egg meet, the fertilized egg forms a free-swimming larva, what Widmer describes as "a fuzzy ciliated tic tac." It whizzes around before landing on a sponge or other seafloor fixture. There it morphs into a weedy little polyp, an intermediate form that can reproduce asexually. And then—well, sometimes nothing happens for a good long while. A jellyfish polyp can sit dormant for a decade or more, biding its time.

When ocean conditions become ideal, however, the polyp starts to "strobilate," or bud off new jellyfish, a process Widmer shows me under a microscope. One polyp looks as if it is balancing a stack of Frisbees on its head. The tower of tiny discs pulses slightly. Eventually, Widmer explains, the top one will fly off, like a clay pigeon at a shooting range, then the next one, and the next. Sometimes dozens of discs launch, each disc a baby jellyfish.

To test the impact of warming oceans on polyp productivity, Widmer assembled a series of incubators and seawater baths. If he heated each a few degrees warmer than the last, what would the jellyfish do? At 39 degrees Fahrenheit, the polyps generated, on average, about 20 teeny jellyfish. At 46 degrees, roughly 40. The polyps in 54-degree seawater birthed some 50 jellies each, and one made 69. "A new record," Widmer says, awed.

To be sure, Widmer has also found that some polyps can't


MARINE ADVISORY
More than 500 "dead zones" around the world (in red) are so depleted of oxygen that few sea creatures survive.
NORTH AMERICA
EUROPE
AFRICA
ASIA
HYPOXIC SYSTEMS (DEAD ZONES)

PLOS ONE; MAP: GUILBERT GATES (SOURCE: ROBERT DIAZ, VIRGINIA INSTITUTE OF MARINE SCIENCE, COLLEGE OF WILLIAM AND MARY)

produce young at all if placed in waters significantly warmer than their native range. But his experiments, which confirm research on other jellies done by Purcell, also lend some credence to anxieties that global warming may induce jelly extravaganzas.

TWO EVENTS ULTIMATELY stalled the *Mnemiopsis* invasion in the Black Sea. One was the fall of the Soviet Union: in the ensuing chaos, some farmers ceased fertilizing their fields and water quality improved. The other was the accidental introduction of a second exotic jellyfish that happened to have a taste for *Mnemiopsis*.

In lieu of dismantling superpowers or importing invasive species, countries have adopted jelly-proofing strategies. South Korea recently released 280,000 native, jelly-eating filefish along the coast of Busan. Spain dispatched indigenous loggerhead sea turtles off Cabo de Gata. Japanese fishermen hack at the giant Nomura's with barbed poles. Mediterranean beaches have organized jellyfish hot lines, spotter boat armadas and airplane flyovers; the slimy troublemakers are sometimes sucked up by garbage scows, carted off by backhoes or used for fertilizer. Bathers in the worst areas are advised to wear full-body Lycra "stinger suits" or pantyhose or to smear themselves with petroleum jelly. Most sting-treatment products feature vinegar, the best remedy for jelly venom.

When, nearly two decades ago, Daniel Pauly, a fisheries biologist at the University of British Columbia, started warning of the dangers of overfishing, he liked to alarm people and say we would end up eating jellyfish. "It's not a metaphor anymore," he says today, pointing out that not only China and Japan but also the U.S. state of Georgia have commercial jellyfish operations, and there's talk of one starting in Newfoundland, among other places. Pauly himself has been known to nibble jellyfish sushi.

NO. 2
IF ACIDITY KEEPS RISING, CORAL REEFS, A KEY TO MARINE LIFE, WILL BE DEVASTATED.

About a dozen jellyfish varieties with firm bells are considered desirable food. Stripped of tentacles and scraped of mucous membranes, jellyfish are typically soaked in brine for several days and then dried. In Japan, they are served in strips with soy sauce and (ironically) vinegar. The Chinese have eaten jellies for 1,000 years (jellyfish salad is a wedding banquet favorite). Lately, in an apparent effort to make lemons into lemonade, the Japanese government has encouraged the development of haute jellyfish cuisine—jellyfish caramels, ice cream and cocktails—and adventuresome European chefs are following suit. Some enthusiasts compare the taste of jellyfish to fresh squid. Pauly says he's reminded of cucumbers. Others think of salty rubber bands.

The main edible variety in U.S. waters, cannonball jellies, are found on the Atlantic Coast from North Carolina to

ABIGAIL TUCKER *is a staff writer.* **JOHN LEE***'s photographs have run in* SMITHSONIAN *articles about tomatoes and John Muir.*

CHRISTIAN ZIEGLER

MARINE ADVISORY

Scientists say the outlook for the world's oceans is bleak—unless we stop overfishing and reduce air and water pollution. Here's an update on the marine environment and its possible future. **SARAH ZIELINSKI**

16.1 **billion pounds:** total amount of fish that commercial fleets kill or fatally injure before discarding at sea each year

3 **pounds:** amount of wild mackerel or anchovies needed to produce one pound of farmed shrimp or salmon

82.4 **percent:** decline in the spawning population of western bluefin tuna since 1970

33 **percent:** amount of U.S. crude oil production from offshore sources

0.7 **parts per billion:** concentration of weathered crude oil in seawater that kills or damages Pacific herring eggs

100 **percent:** projected increase, by 2100, in the number of coastal dead zones, where bacteria spurred by pollution deplete oxygen from the water and make it impossible for marine animals to survive

0.7 **percent:** proportion of the world's oceans that are part of marine protected areas

15 **million years ago:** the last time CO_2 levels in the atmosphere were as high as they are today

2037 **projected year** when the Arctic will become almost entirely free of summer sea ice due to melting

2050 **projected year** when coral reefs worldwide will shrink because of increased ocean acidity as atmospheric carbon dioxide, from burning fossil fuels, dissolves in seawater

Nancy Knowlton (below), a marine biologist at the Smithsonian's National Museum of Natural History and a leading authority on coral reefs, says a significant increase in ocean acidity puts virtually all marine animal species at risk. That's because acid can kill larval fish and shellfish and keep corals and animals at the base of the marine food web from building skeletons. "In the long term," Knowlton says, "if we don't deal with carbon dioxide emissions, we're in real trouble."

Florida and in the Gulf of Mexico. They scored quite high on a "hedonic scale" of color and texture in a study led by Auburn University. Another scientific paper hailed jellyfish flesh—which is 95 percent water, a few grams of protein, the barest hint of sugar, and, once dried, only 18 calories per 100-gram serving—as "the ultimate modern diet food."

THE RESEARCH VESSEL *Point Lobos* heaves in the swells of Monterey Bay. After a two-hour ride from shore, the engine idles as a crane lowers the *Ventana*, an unmanned submarine stocked with a dozen glass collecting jars, into the water. As the submarine begins its descent into the canyon, its cameras feed footage to computer monitors in the boat's dark control room. Widmer and other scientists watch from a semicircle of armchairs. Widmer is allotted only a few trips on the MBARI submarine each year for his research; his eyes are shining with anticipation.

On the screens we see the bright green surface water darken by degrees to deep purple, then black. White flecks of detritus called marine snow rush past, like a star field in warp speed. The submarine drops 1,000, 1,500, 5,000 feet. We are en route to what Widmer has modestly named the Widmer Site, a jellyfish mecca on the lip of an undersea cliff.

Our spotlight illuminates a Gonatus squid, which clenches itself into an anxious red fist. Giant gray-green Humboldt squid sail by, like the ghosts of spent torpedoes. Glimmering beings appear. They seem to be constructed of spider webs, fishing line and silk, soap bubbles, glow sticks, strands of Christmas lights and pearls. Some are siphonophores and gelatinous organisms I've never seen before. Others are tiny jellyfish.

NO. 3
BECAUSE OF OVERFISHING AND POLLUTION, THE CATCH OF THE DAY WILL BE JELLYFISH.

Every now and then, Widmer squints at an iridescent speck, and—if it isn't too delicate, and the gonads look ripe—asks the pilot of the remote-controlled sub to give chase. "I don't know what it is, but it looks promising," he says. We bear down on jellyfish the size of jingle bells and gumdrops, slurping them up with a suction device.

"Down the tube!" Widmer cries in triumph.

"In the bucket!" the pilot agrees.

The whole boat crew pauses to stare at the screen and marvel at a piece of kelp studded with fuzzy pink anemones. We snatch a jelly here, a jelly there, including a mysterious one with a strawberry-colored center, always keeping a sharp eye out for polyps.

The submersible sails over the wreck of a blue whale, a gigantic rockfish curled up like a cat beside the great skull. We pass a frilly albino sea cucumber and a Budweiser can. We see squat lobsters and spot prawns, bleached sea stars, black owl fish, bouncy coils of eggs, a pale pink orb with tarantula-like legs, lemon-yellow mermaid's purses, English sole, starry flounders and the purple bullet shapes of sharks. The California sunshine seems dismal in comparison.

When the submarine surfaces, Widmer quickly packs his tiny captives into chilled Tupperware containers. The strawberry jelly begins to languish almost immediately, as the sunlight disintegrates the red porphyrin pigment in its bell; soon it will be floating upside down. A second unknown specimen with pinwheel-shaped gonads looks perky enough, but we have caught only one, so Widmer will not be able to breed it for public display. He hopes to retrieve more on the next trip.

He has, however, managed to corral half a dozen *Earleria corachloeae*, a species he recently discovered. He named it after his two young landlocked nieces in Wichita, Kansas—Cora and Chloe. Widmer produces a YouTube series for them called "Tidepooling With Uncle Chad," which introduces ocean wonders—sea turtle nests, bull kelp trumpets, snail racetracks—he wants them to know.

Two days later, the *E. corachloeae* produce a smattering of eggs like grains of fine beach sand. He will dote on his captives until they die or go on display. They are officially "golden children."

Daniel Pauly (above) has warned for decades that if overfishing continues, jellyfish could be some of the only seafood left to eat. Jellyfish are already a delicacy in parts of Asia (opposite top: a fishery in southern China) and at least one species native to U.S. coastal waters (opposite bottom: *Stomolophus meleagris*, or cannonball jellyfish, found in the Southeast) is edible.

Share this story and learn more about these creatures at smith.hy.pr/jellyfish

MARTIN DEE / UNIVERSITY OF BRITISH COLUMBIA; PP. 34 RANDY OLSON; RON LARSON

CHARGING AHEAD

An entrepreneur hits the road with a new approach to the electric car that overcomes its greatest shortcoming BY JOSHUA HAMMER

PHOTOGRAPHS BY AHIKAM SERI

Shai Agassi (at a corporate facility outside Tel Aviv) founded a company whose name reflects his determination to improve the world.

IN THE MIDDLE OF 2007, SHAI AGASSI, A SOFTWARE multimillionaire turned environmental entrepreneur, was pondering how to make an electric car affordable to the average Joe. At that point, the all-electric vehicle—as opposed to electric-gasoline hybrids such as the Toyota Prius—was widely derided as impractical. General Motor's EV1 had appeared in 1996 and, despite its cultlike following, the company stopped producing it after three years, saying the program was not commercially successful. The most advanced electric vehicle, the Tesla Roadster, was about to be released; it would travel some 200 miles on a fully charged battery, but at $109,000, the sleek sports car would be accessible only to the affluent; the company says about 1,200 of the vehicles are on the road. More affordable cars, at the time mostly in the planning stages, would be equipped with batteries averaging just 40 to 100 miles per charge. The power limitations had even spawned a new expression—"range anxiety," the fear of being stranded with a dead battery miles from one's destination.

Then, on a scouting trip to Tesla's northern California plant, Agassi had an epiphany: "I scribbled down on a

piece of paper, 'batteries consumable. They're like oil, not part of the car.' That's when it dawned on me—let's make the batteries switchable."

Two years later, in a cramped booth behind the exhibition hall at the Frankfurt Auto Show, Agassi was celebrating the payoff of that epiphany. The California company he founded, Better Place, had just announced its biggest deal yet: an agreement with Renault, the French car manufacturer, to produce 100,000 all-electric vehicles, or EVs, for sale in Israel and Denmark starting in 2010. Around the corner at the giant Renault exhibition, a garishly lit display showed a stylized version of one of Agassi's "switching" stations in action: a robot with a steel claw extracted and replaced a model of a 600-pound battery from a cavity in the bottom of the vehicle in three minutes.

"We use the same technology that F-16 fighters use to load their bombs," said Agassi, an Israeli-American, who got the inspiration from a pilot in the Israel Defense Forces.

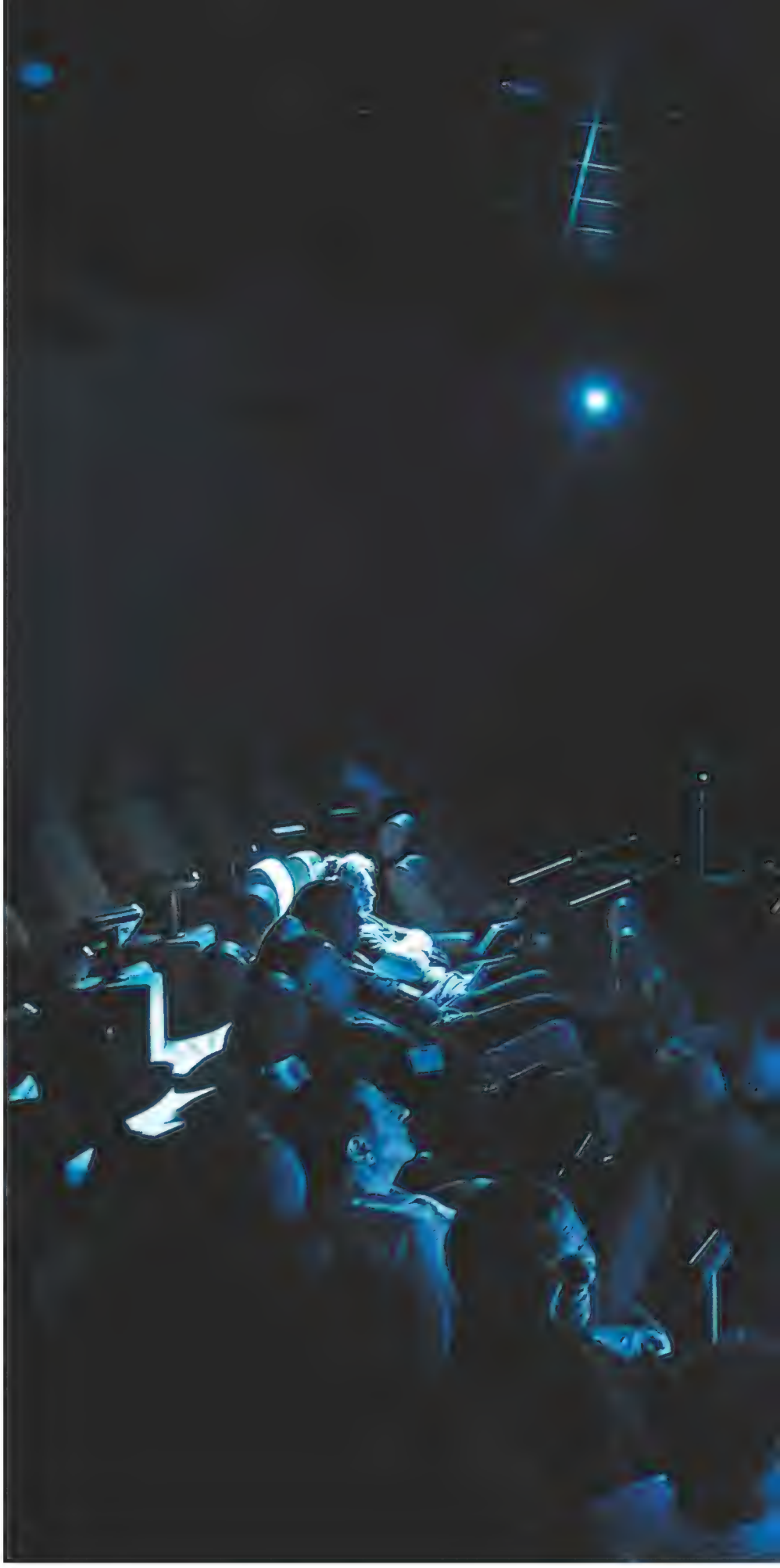
If Agassi's dream once seemed premature, concern about global warming, government pressure to produce zero-emissions vehicles, high oil prices and rapid improvements in lithium-ion batteries have begun to make electric vehicles look increasingly viable. By 2013, several models will have hit the road, including the Smart Fortwo, made by Daimler; the Nissan Leaf; the Mitsubishi i-MiEV; the Chevrolet Volt; and Tesla's Model S.

Governments are trying to accelerate the shift away from fossil fuels. The Obama administration is providing $2.4 billion in research-and-development grants to electric car and battery manufacturers to improve vehicle battery technology. The Chinese have pledged to put half a million alternative-fuel cars on the road by 2011.

"In 2007 you could barely see an electric car" at the Frankfurt Auto Show, says Agassi, an intense 42-year-old, coolly elegant in a black tieless suit. "If you walked around talking about EVs, everybody assumed you were smoking something."

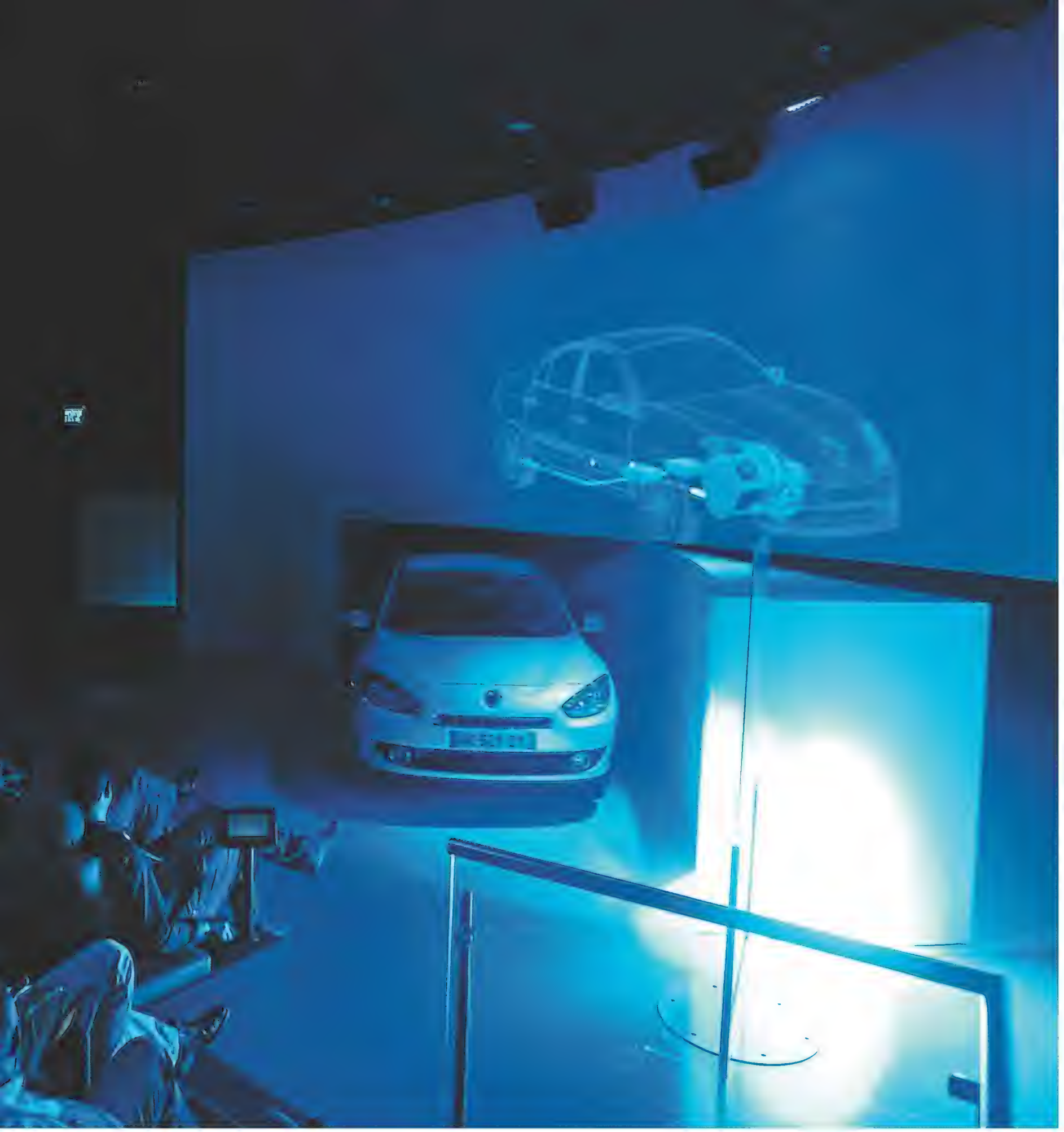
NO. 4
JUST AS CELL PHONES ARE GIVEN AWAY TODAY, ELECTRIC CARS WILL BE FREE.

Agassi's business plan is unique among electric-car service providers. Others will make the vehicles. He will lease the batteries to car owners, and sell access to his switching and charging network. He expects to make his money selling miles, much as a cellphone-service provider sells minutes. Subscribers to Agassi's plan would be entitled to pull into a roadside switching station for a battery change or to plug into a charging station, where dozens of other cars might also be hooked up, for an overnight or workday charge. Agassi estimates his customers will pay no more for battery power than they would spend on gasoline to travel the same distance. As business grows and costs fall, Agassi says, profits will soar. He says eventually he might give cars away, just as cellular-service providers offer free phones to customers with long-term contracts.



AGASSI WAS BORN IN A TEL AVIV SUBURB—his father is an electrical engineer and his mother a fashion designer—and he began programming computers at age 7. He has already had one hugely successful career. In his early 20s he founded a software company, TopTier, that helped corporations organize data; at age 33, he sold it to the German software giant SAP for $400 million. He later became SAP's chief of technology. Flush with cash and looking for a new challenge, he turned to global warming. At a gathering of young leaders at the World Economic Forum in Davos, Switzerland, in 2005, Agassi and other attendees were asked, "How do you make the world a better place?"

The challenge, he recalled to me, was "to do something



Visitors at a facility near Tel Aviv view a diagram of the Fluence Z.E. electric engine. Better Place vehicles are built by the French corporation Renault, which plans to sell 100,000 of the battery-powered cars in Denmark and Israel over the next five years.

more meaningful than create a new version of software. How do you run a country without oil, on today's state-of-the-shelf technology?"

It took him a year to consider the options for propelling a vehicle—biofuels, hybrids, hydrogen—before settling on electricity. In the fall of 2006, in a talk he gave at Tel Aviv's Saban Center for Middle East Policy about running a nation without oil, he mentioned his interest in electric car technology. A week later, Agassi says, he got a call from future Israeli President Shimon Peres, who expressed interest in the concept. Peres introduced Agassi to Prime Minister Ehud Olmert, and, at Davos in 2007, brought him together with Carlos Ghosn, the CEO of Renault. The partnership was formed "very quickly," says Patrick Pélata, Renault's chief operating officer. "We were already working on electric cars, and we realized you need three things—a cheap way of charging a battery at home or the office, a quick charge method and a quick drop for people who want their cars for a longer range. Agassi was the only one proposing that." Agassi quit SAP and, in 2007, founded Better Place in Palo Alto, California. He at-

tracted $200 million from investors, including the Israel Corporation, which owns oil refineries, and investment bank Morgan Stanley. This past January, Agassi announced another $350 million from backers led by the British bank HSBC, raising his investment total to $700 million.

Israel is a natural launching point for electric vehicles because of its small size, seldom-crossed borders and sensitivity to fossil-fuel dependency. The company plans to open its first switching station in Israel near Tel Aviv this year; the goal is to expand to 70 by the end of 2011. Agassi has installed thousands of "charge spots" in garages and parking lots, where drivers can plug in their Renaults for the standard four- to eight-hour, 220-volt recharge. Renault says it hopes to sell 100,000 electric vehicles in Israel and Denmark over the next five years—each equipped with a modified GPS system that will direct drivers to the nearest battery-swapping station or charge point. The vehicle, which can travel about 100 miles on a charge, will reportedly cost $25,000 to $30,000; Better Place hasn't disclosed the cost of a battery-servicing contract.

Agassi and Better Place (a charging spot) have "the lead on everybody else," says one automobile analyst.

Agassi also hopes to work with an Israeli utility company to purchase electricity from solar generators, to reduce his company's carbon footprint. "The company is looking at the whole process, from the technology inside the car, to the infrastructure, to the charge spots and the connectivity that make all the pieces work together," says Thilo Koslowski, an automotive analyst with Gartner Incorporated, a Stamford, Connecticut-based consulting firm specializing in high-technology industries. "Agassi has the lead on everybody else."

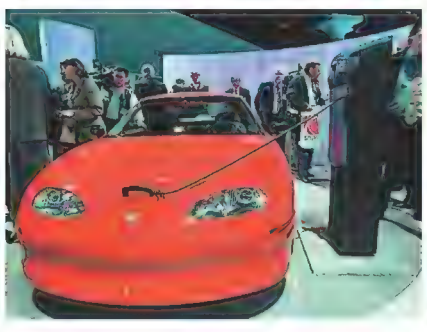
Agassi is focusing his rollout on what he calls "transportation islands," largely self-contained areas that are receptive to electric cars. In Denmark, the largest utility, Dong Energy, is investing $130 million to help provide charge spots and switching stations for Better Place vehicles, and will provide the facilities with wind-generated electricity. Also, the Danish government is temporarily offering citizens a reported $40,000 tax break to buy an electric car—plus free parking in downtown Copenhagen.

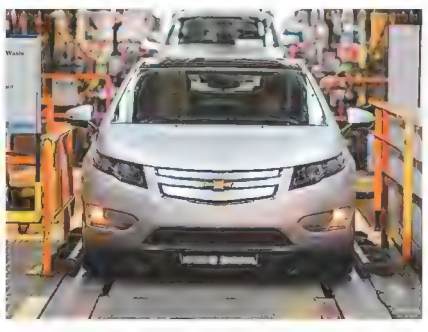
In April, Better Place began working with Japan's largest taxi company to set up a battery-switching station in Tokyo and test four battery-powered cabs. Better Place has plans to operate in Canberra, Australia, and to run a pilot program in Oahu, Hawaii, by 2012.

Agassi is also aiming for the continental United States. He says he has spoken with San Francisco Mayor Gavin Newsom about building switching stations in the Bay Area. (In December, Newsom and other Bay Area community leaders announced a deal with Nissan—projected cost of the Nissan Leaf is $25,000, after tax credits—to install home-charging units for consumers.) Agassi says he dreams of the day when the big three U.S. automakers sign on to his plan and Better Place infrastructure blankets the country. "With about $3 billion to $5 billion, we can put switching stations across the five major U.S. corridors—West Coast, Northeast, Southeast, Midwest and South," he says, his voice jumping an octave with enthusiasm. "We can't fail," he insists.

BUT OTHERS SAY HE CAN. The particular battery he has adopted in partnership with Renault may not be accepted by other car manufacturers. That would sharply limit the number of vehicles he could service, or it would force him to stockpile different batteries for different car models, substantially raising his costs. Moreover, lithium-ion battery technology is improving so quickly that Agassi's switching stations, which cost nearly $1 million apiece, may quickly become as obsolete as eight-track tapes. "If we have

The modern electric car proceeded by fits and starts in the U.S. market. From left: The General Motors EV1 debuted in 1996, garnered fans, then ceased production after three years; the Nissan Leaf is due out in December; the Tesla Roadster goes from 0 to 60 mph in under four seconds and costs $109,000; the electric plug-in/gas hybrid Chevrolet Volt is to hit showrooms in late 2010.





BELOW: HAL GARB / AFP / GETTY IMAGES; TORU YAMANAKA / AFP / GETTY IMAGES; TESLA MOTORS; JOHN F. MARTIN / GENERAL MOTORS / GETTY IMAGES

JOSHUA HAMMER, *a frequent contributor, is based in Berlin. Work by the Jerusalem-based photographer* **AHIKAM SERI** *previously appeared in* SMITHSONIAN *in an article about the Dead Sea Scrolls.*

A real-world test of the Better Place concept got underway this past spring in Tokyo, where four taxicabs were put through their paces. Above: a taxi parks over the gap in a battery-switching station. Below: beneath the car, an electric lift removes the spent 400-pound boxlike battery assembly, unloads it and installs a fresh one. The exchange takes three minutes, the company says.

BETTER PLACE (2)

a breakthrough, with 300 to 600 miles per charge, the whole thing could be derailed," says analyst Koslowski.

Better Place also faces difficulties breaking into markets. Without considerable tax incentives, customer rebates and government subsidies for electric car and battery makers, weaning Americans off gasoline will be a challenge. "The U.S. imports more oil than any other country and [gas] prices are the lowest in the West," Agassi says. Even in Europe, where gasoline costs up to three times as much as it does in the United States, progress has been slower than expected. In Denmark, Agassi promised to have 100,000 charging spots and several thousand cars on the road by 2010, but so far he's got just 55 spots and no cars. Better Place spokesman Joe Paluska says the company scaled back "while it worked out better design and implementation processes ahead of full-scale commercial launch in 2011."

Terry Tamminen, an adviser on energy policy to California Governor Arnold Schwarzenegger and author of *Lives Per Gallon: The True Cost of Our Oil Addiction*, says Agassi's faith in battery-powered vehicles is excessive. The technology's drawbacks, Tamminen says, include the potential drain on the electrical grid and the vast new infrastructure needed—such as tens of thousands of charging spots for the Bay Area alone—and the mileage limitations of even the best batteries. Tamminen, who also served as the head of the California Environmental Protection Agency, believes hydrogen-powered cars will play a role (he drives one himself). They use hydrogen fuel derived mainly from natural gas or other fossil fuels to generate electricity and power the engine; but Tamminen points out that hydrogen fuel can also be derived from water, and dishwasher-size machines that extract hydrogen from water will be available to consumers in 2013. Under the Hydrogen Highway Network, California has installed 30 hydrogen-fueling stations. "Yesterday I drove 150 miles to Palm Springs from Los Angeles in my hydrogen-powered electric car. I refueled in seven minutes and was ready to return that afternoon," he told me.

But hydrogen fuel faces obstacles, too. U.S. Energy Secretary Steven Chu last year tried to eliminate federal funding for research into hydrogen cars; he cited the high cost and questionable durability of fuel cells, the expense of building a refueling infrastructure and the reliance of most hydrogen-generating processes on fossil fuels. (Congress, however, restored some funding.)

Agassi told me hydrogen power is an "idiotic idea" because the infrastructure to support it would have to be created from scratch; in contrast, electric batteries rely on the existing power grid.

Experts are dubious, but Agassi envisions battery-switching stations across a broad swath of the United States.

By 2020, Agassi predicts, half of all cars bought in the United States and Europe will be electric. Others say Agassi's estimate is overblown. Renault's Pélata says a better guess might be 10 percent. Rod Lache, an analyst with Deutsche Bank Equity Research, says Better Place could be a financial success even if it occupies a small niche. "It could get 10 percent of the market in Israel and still be hugely profitable. Beyond that, it's hard to say."

I CAUGHT UP WITH AGASSI at Better Place's new R & D facility, in an industrial park east of Tel Aviv. Agassi, dressed as usual in black, was sitting in a windowless office with unadorned white walls. Carpenters hammered and drilled in the next room. "In Palo Alto I have a cubicle," he said. "I don't travel with an entourage. It's all strictly bare bones." He had flown from the United States for the final countdown to what his company calls the Alpha Project—the opening of the first switching station and a visitor center, near Tel Aviv. Some 8,000 people have dropped by the center this year to test-drive a Renault EV. Down the hall, in a glass-walled conference room, a score of Better Place employees were working out logistics, such as whether to locate the switching stations underground or at street level.

Next door a pair of software engineers showed me a computer program designed to regulate the electricity flow into the company's charge spots. A recent simulation by Israel's main utility indicated that the nation might have to spend about $1 billion on new power plants if every car was electric by 2020. But Better Place says "smart grid management," or generating electricity only when it's needed and sending it only where it's needed, could reduce the number of new plants. Company designer Barak Hershkovitz demonstrated the company's role in making the grid smarter: five electric cars hooked up at a charge post in the company garage used 20 percent less power than they would have consumed without smart-grid management. Likewise, he told me, to avoid straining the grid, a central computer could keep track of every car being charged in Israel and regulate the juice flow.

To Agassi, such problems are now a matter of fine-tuning. "If [the company's] first two years were about using brains to solve a puzzle," Agassi told me, "the next two years are about using muscle to install [the equipment] in the ground." Soon, he says, gasoline-powered cars will be "a relic of the past," and maybe ten electric-car companies, including Better Place, will dominate the global market. "Together," he says, "we will have tipped the entire world."

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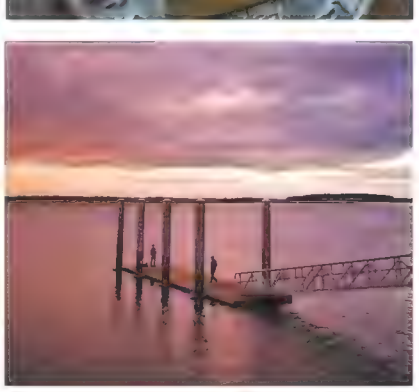
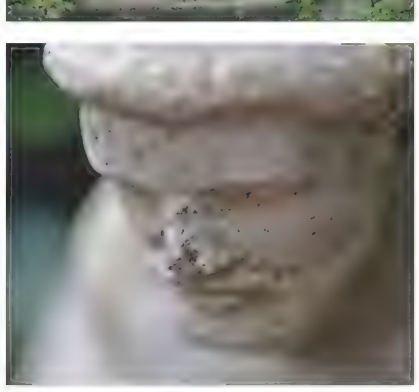
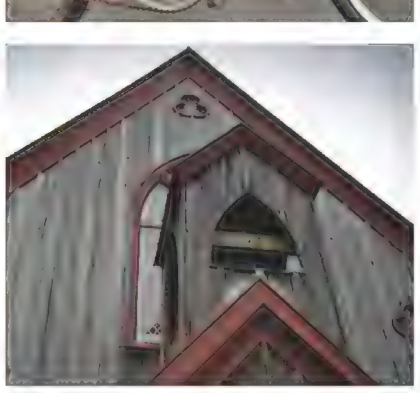
The best way to be inspired

IS TO SEE NEW THINGS.
AND OLD ONES, TOO.



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THE ENVIRONMENT

40 THINGS TO KNOW

Q&A

RICHARD BRANSON INDUSTRY IN ORBIT

RICHARD BRANSON WAS BORN IN SURREY, *England, and founded Virgin Records in 1970 at age 20. The brand now includes more than 300 companies, including Virgin Atlantic Airways, Virgin Trains and Virgin Galactic, a venture that, by 2012, is expected to ferry six passengers 68 miles above the Earth at a cost of $200,000 each. Sir Richard, who conducts business from a private island in the British Virgin Islands, exchanged e-mails with the magazine's Megan Gambino.*

Why commercial space travel?

Industrial and scientific development in the void of space that surrounds our delicate planet will help us carry on living on Earth over the next century. Satellites already deliver information (through agricultural weather satellites and the GPS system) that provides the extra margin of food that keeps nearly a billion people a year from starving. Today's generation has the technological ability to do more industrial work up there, providing communications, advanced science and even, potentially, solar power and [computer] server farms in space—thus taking CO_2-intensive industry out of the atmosphere. The challenge is to get the technology up there in a safe, reliable and cheap way with minimal environmental impact. Nonreusable rockets launched from the ground based on designs from the 1940s are not the answer. It will come from the private sector working with—and independent of—agencies like NASA to bring new materials and technologies into space.

NO. 5

TO TAP NEW SOURCES OF CLEAN ENERGY, PEOPLE WILL DO BUSINESS IN SPACE.

The future for trains?

Rising oil prices, road congestion and tougher tax policy on aviation will force consumers to radically reduce their dependency on car and, yes, domestic air travel. The likely result is that more consumers will turn to rail for domestic travel. It will continue to expand as major manufacturers develop a range of high-speed trains using technology based on non-fossil fuels.

What alternatives are attainable by 2050?

We face an oil peak well before 40 years is up, making it urgent to rid our dependence on imported oil. There is much debate about just how much oil is left in the world, but what is certain is we have seen the last of the cheap oil, and the price of extracting it is only going up as it gets harder to do. We must work faster to change consumer behavior and develop alternative sources of power. Lightweight carbon composite materials will mean it will take less time for us to travel great distances and require less-dirty fuels. Environmental issues are not a charitable adjunct to normal day-to-day business. Governments must issue clear targets to encourage the adoption of electric cars and incentives to invest in renewable fuels and technologies.

THE CHALLENGE

Branson (in a replica spaceship) wants to place CO_2-intensive activities above Earth.

RICHARD BAKER

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Norman Rockwell, Movie Starlet and Reporters (detail), 1936. Collection of Steven Spielberg, ©1936 SEPS: Licensed by Curtis Publishing, Indianapolis, IN. All rights reserved. Photo © 2010 American Illustrators Gallery™ NYC

BUYING TIME

For scientists in a remote corner of coastal North Carolina, ignoring global warming is

WHEN A BUTTERMILK MOON RISES OVER ALLIGATOR River, listen for red wolves. It's the only spot in the world where they still howl in the wild. Finer boned than gray wolves, with foxier coloring and a floating gait, they once roamed North America from the Great Lakes to the Gulf of Mexico. By the mid-1970s, because of overhunting and habitat loss, just a few survived. Biologists captured 17 and bred them in captivity, and in 1987 released four pairs in North Carolina's Alligator River National Wildlife Refuge.

Today more than 100 red wolves inhabit the refuge and the surrounding peninsula—the world's first successful wolf reintroduction, eight years ahead of the better-known gray wolf project in Yellowstone National Park. The densely vegetated Carolina refuge is perfect for red wolves: full of prey such as white-tailed deer and raccoons and practically devoid of people.

Perfect, except it may all be underwater soon.

Coastal North Carolina is more vulnerable than almost anywhere else in the United States to sea-level rise associated with climate change, and the 154,000-acre Alligator River refuge could be one of the first areas to go under. A stone's throw from Roanoke Island, where the first English colony in North America was established in the 1580s, it's a vibrant green mosaic of forest, piney swamp and salt marsh. I've seen a ten-foot alligator dreaming on a raft of weeds, hundreds of swallowtail butterflies rising up in giddy yellow spirals and scores of sunbathing turtles. The refuge has one of the highest concentrations of black bears on the East Coast. It is home to bobcats and otter and a haven for birds, from great blue herons to warblers to tundra swans. Most of it lies only about a foot above sea level.

Scientists at Alligator River are now engaged in a pioneering effort to help the ecosystem survive. Their idea is to help shift the entire habitat—shrubby bogs, red wolves, bears and all—gradually inland, while using simple wetland-restoration techniques to guard against higher tides and catastrophic storms. At a time when many coastal U.S. communities are paralyzed by debate and hard choices, such decisive action is unusual, if not unique.

"We're on the front line here," says Brian Boutin, a Nature Conservancy biologist leading the Alligator River adaptation project. "We're going to fight [sea-level rise] regardless. But it matters whether we fight smart or fight dumb."

Sea level has been increasing since the peak of the last ice age 20,000 years ago, when the glaciers began melting. The rise happens in fits and starts; in the Middle Ages, for instance, a 300-year warming period sped it up slightly; starting in the 1600s, the "Little Ice Age" slowed it down for centuries. But scientists believe that the rate of rise was essentially the same for several thousand years: about one millimeter per year.

NO. 6
IN ONE STRETCH OF THE EAST COAST, OYSTERS WILL HELP WOLVES ESCAPE CLIMATE CHANGE.

Since the Industrial Revolution, however, the burning of fossil fuels has increased the amount of carbon dioxide and other gases in the atmosphere, which trap the earth's reflected heat—the now familiar scenario called the greenhouse effect, the cause of global warming. The rate of sea-level rise around the world has tripled over the past century to an average of about three millimeters a year, just over a tenth of an inch, because of both melting glaciers and the expansion of water as it warms.

In 2007, the Intergovernmental Panel on Climate Change predicted seven inches to two feet of global sea-level rise by 2100. Some scientists, however, think it will be more like six feet. Such wildly varying predictions are the result of huge unknowns. How much of the gargantuan ice sheets in Greenland and West Antarctica will melt? How will human popula-

not an option

BY ABIGAIL TUCKER PHOTOGRAPHS BY LYNDA RICHARDSON

tions affect greenhouse gas emissions? Will ocean currents change? Will the water rise steadily or in spurts?

Making matters worse, the mid-Atlantic region lies on a section of the earth's crust that is sinking one or two millimeters a year. In the last ice age, the continental plate on which the region sits bulged upward like a balloon as massive glaciers weighed down the plate's other end, in what is now the Great Lakes region. Ever since the glaciers began to melt, the mid-Atlantic has been falling back into place. The inexorable drop compounds the effects of sea-level rise.

Taking all the data into account, a panel of North Carolina scientists told the state this past spring to prepare for a three-foot rise by 2100, though some regional experts think that estimate is low. (The only places in North America more imperiled are the Mississippi River delta, the Florida Keys and the Everglades.)

Moreover, as the ocean surface warms, some experts predict that stronger storms will hit the Atlantic Seaboard. A major hurricane could bring extreme tides and crashing waves, which can make short work of a wetland. In 2003, scientists in Louisiana predicted that the state stood to lose 700 square miles of wetlands by 2050. Two years later, during hurricanes Katrina and Rita, 217 square miles vanished practically overnight.

Already at Alligator River, salty water from the surrounding estuaries is washing farther inland, poisoning the soil, Boutin says. The salt invasion triggers a cascade of ecological change. The pond pines turn brown and the dying forest is overrun by shrubs, which themselves wither into a dead gray haze. A salt marsh takes over, until it, too, is transformed, first into little jigsaw pieces of land and finally into open water.

Boutin says his team has a decade or less to act. "If we don't stop the damage now, it's all going to start crumbling," he says. "We don't want the transition to open water to happen so quickly that the species that depend on the land don't have enough time." Sea walls and other traditional engineering techniques aren't an option, he says, because sheltering one portion of coast can speed erosion in another or choke the surrounding wetlands.

Healthy wetlands can keep up with normal sea-level fluctuation. They trap sediment and make their own soil by collecting organic matter from decomposing marsh plants. Wetlands thereby increase their elevation and can even slowly migrate inland as the water rises. But the wetlands can't adapt if the seawater moves in faster than they can make soil.

The Alligator River project aims to buy time for the ecosystem to retreat intact. Boutin and co-workers hope to create migration corridors—passages for wildlife—connecting the refuge with inland conservation areas. But the

Red wolves (inset) are now thriving in Alligator River National Wildlife Refuge, thanks to the world's first successful wolf reintroduction project. But because of rising water and sinking terrain, the animals' new habitat might not last much longer.

To slow the submersion of the refuge, park managers are rerouting waterways, planting salt-tolerant trees and building barrier reefs. From left: Brian Boutin measures water flow; a bald Cyprus sapling sprouts; juvenile oysters will attach to seeded shells.

relocation of plants and animals must be gradual, Boutin says, lest there be a "catastrophic loss of biodiversity."

Boutin drives me in a pickup truck to the edge of a vast marsh full of salt meadow hay and black needle rush. Small waves smack the shore. In the distance, across Croatan Sound, we can see the low-slung island of Roanoke. This is Point Peter, the project's testing ground.

Like many East Coast swamps, Alligator River is criss-crossed with man-made drainage ditches. Workers will plug some of those ditches or outfit them with gates, to keep the saltwater back at least awhile.

There are 40 acres of newly planted saplings—native bald Cyprus and black gum, which are salt- and flood-tolerant—intended to keep the forest in place a bit longer as the sea level rises. Wolves, bears and other animals depend on the forest, and "we're holding the line to allow them to use the corridors" to get to higher ground, Boutin says.

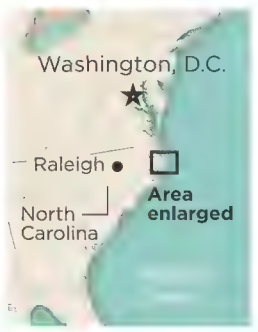
Out in the water, white poles stake the outline of an artificial reef that is scheduled to be built soon. Made of limestone rock poured from a barge, the reef will attract oysters and shield the marsh edge from violent waves. This living buffer will also cleanse the water and create habitats for other marine animals, increasing the marsh's resilience. In other places, the scientists will restore aquatic plants and remove invasive grasses.

The biologists are evaluating their efforts by counting oysters and fish, testing water quality and, with aerial photography, assessing erosion. If successful, the project will be replicated elsewhere in the refuge, and maybe, the scientists hope, up and down the East Coast.

"The next generation may say 'Wow, they did it all wrong,'" says Dennis Stewart, a U.S. Fish and Wildlife Service biologist working on the project. But, he adds, "I would rather future generations look back and say, 'Well, they tried to do something,' rather than 'They just sat around.' We got tired of talking and decided to do something about this."

One spring day, David Rabon, the USFWS red wolf recovery coordinator, takes me along with his tracking team to look for new pups belonging to a group called the Milltail Pack. The shady forest, crocheted with spider webs, is remarkably peaceful, the sunlit leaves like green stained glass. I hang back until a sharp whistle cracks the silence: the trackers have found the den, a cozy nook beneath a fallen tree, in which seven velveteen beings squirm and mewl toothlessly. Fourth-generation wild wolves, they are about 6 days old.

Their den will probably be submerged one day. The land that was the red wolves' second chance at wildness will likely become a windblown bay. But if the climate adaptation project succeeds, and future generations of red wolves reach higher ground a few miles to the west, packs may once again prowl a verdant coastline, perhaps even a place reminiscent of Alligator River.



ABIGAIL TUCKER *is a staff writer.* **LYNDA RICHARDSON** *shot Venus flytraps for* SMITHSONIAN.

VANISHING COASTLINE

Sea level is predicted to rise by as much as several feet by the end of the century, swamping much of today's refuge.

MAPS: SAMUEL VELASCO / 5W INFOGRAPHICS

"Eddie said, 'It's ONLY a bad sore throat.'
A little over ONE week later, he's facing leukemia.
I had to find the best place for him. Turns out, it was in Houston."

EDDIE SADDLER
~~leukemia~~

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MEET THE SPECIES

Scientists have discovered thousands of new species in recent years. And there are many more to come

BY RICHARD CONNIFF

ONE MORNING A FEW YEARS AGO, ON A FORESTED slope 6,200 feet above sea level in southwestern Tanzania, a team of wildlife researchers was tracking down reports about a strange primate. The scientists suspected that the animal, known to local hunters as kipunji, would turn out to be imaginary. Then someone yelled "Kipunji!" and everyone turned to gawk at what biologist Tim Davenport of the Wildlife Conservation Society described afterward as "the most bizarre monkey I had ever seen." It was about three feet tall, with a thick fur coat and brownish-gray hair fanned out around its black muzzle like a Victorian gentleman's cheek whiskers. "Bloody hell!" said Davenport. "That's got to be a new species."

It was of course astonishing for a large primate to be discovered in the 21st century in a heavily populated corner of East Africa, where human beings have been kicking around for as long as we have been human. (Scientists now know it as *Rungwecebus kipunji*—the monkey from around Mount Rungwe called kipunji—and think about 1,100 of the animals survive there.) But the truth is that big, colorful, even spectacular, new species seem to be turning up everywhere these days. We are living in what some naturalists have dubbed "a new age of discovery." The number of species being found today "compares favorably with any time since the mid-1700s"—that is, since the beginning of scientific classification—according to Michael Donoghue of Yale University and William Alverson of Chicago's Field Museum. These new species, they write, may be weird enough to induce the same "sense of awe, amusement, and even befuddlement that remarkable new organisms inspired during the last great age of discovery" from the 15th through the 19th centuries.

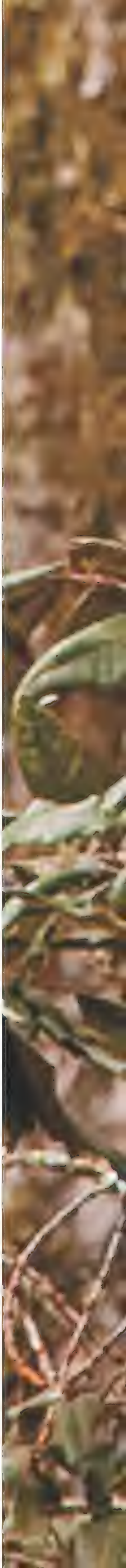
Conventional wisdom says such discoveries should not be happening now. But conventional wisdom always acts as if everything worth knowing is already known and as if all the good stuff has long since been discovered. The great French anatomist Georges Cuvier thought so as early as 1812, discounting the likelihood of "discovering new species of the larger quadrupeds" in the modern world. Then explorers discovered the gorilla, the okapi, the pygmy hippo, the giant panda and the Komodo dragon, among many others.

Nature, the scientific journal, pointed out in 1993 that although one might expect newfound species to be limited to "obscure microbes and insects," scientists in Vietnam had just discovered a bovine. Then others discovered a striped rabbit in the Mekong Delta and a gaudy Indonesian fish that swims by bouncing haphazardly off the sea bottom.

NO. 7
BY 2050, BIOLOGISTS WILL DISCOVER AT LEAST 2,000 NEW MAMMAL SPECIES WORLDWIDE.

Such novelties will turn up for years to come. Scientists estimate the total number of plant and animal species in the world at 10 million to 50 million—but they have so far described only about 1.9 million. (The standard definition of a species is a population of organisms that breed together over time and stay separate from other populations.) Even within our own class, mammals, roughly 300 new species have been discovered in the first decade of this century—mostly rodents, but also marsupials, a beaked whale and a slew of primates. Researchers recently estimated that the total mammal species count will rise from about 5,500 now to 7,500 by mid-century. "And 10,000 wouldn't be a stretch," says Kristofer Helgen, a mammalogist at the Smithsonian's National Museum of Natural History, who has discovered roughly 100 new species.

Why now? New roads and rapid deforestation are opening up habitats once too remote to explore. Re-



TIM DAVENPORT / WCS

The discovery of new species is driven by new technologies, targeted surveys of little-studied ecosystems and a determined effort to identify plants and animals before their habitat is lost. The kipunji (opposite: in Tanzania's highlands) is one of 300 mammal species discovered in the past decade; it is thought to be Africa's rarest monkey.

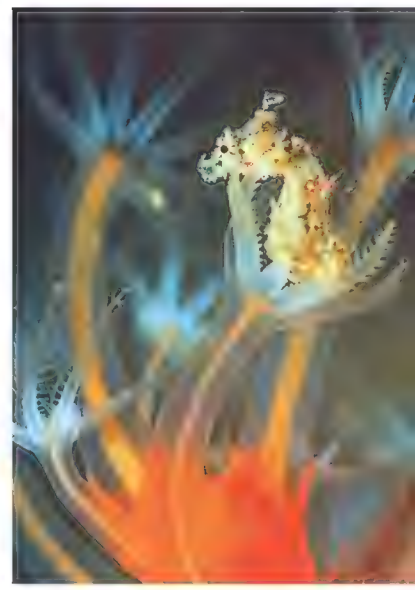
searchers sometimes discover new species just as hunting, farming and other pressures are pushing them to extinction. In addition, helicopters, satellite mapping, submersibles, deep-sea cameras and other modern tools help scientists methodically search understudied areas—including spots where wars or political barriers once kept them out.

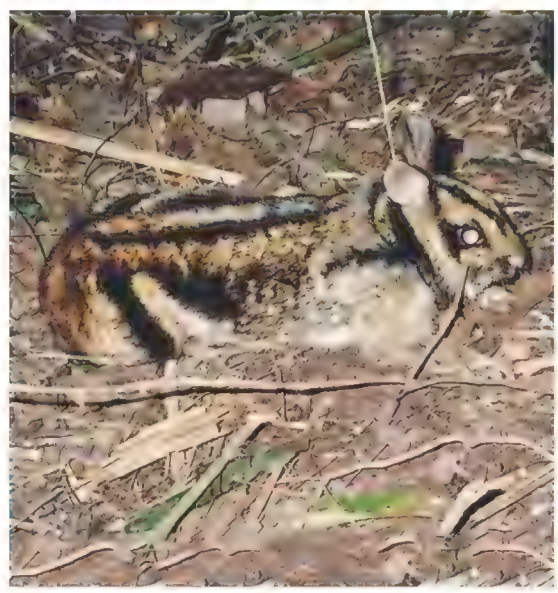
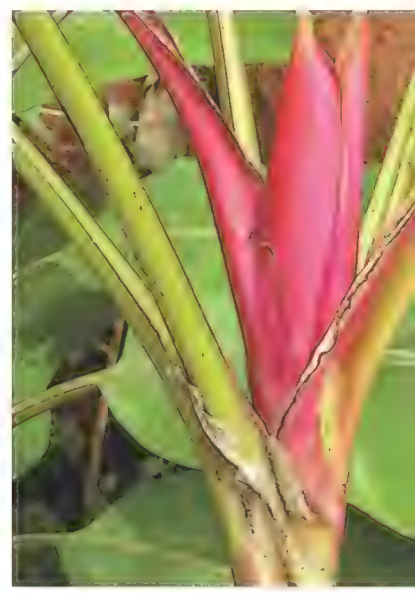
A heightened sense of urgency about the threat of extinction has also encouraged international cooperation, sometimes on a global scale. For instance, the ten-year-long, 80-plus-nation Census of Marine Life will have discovered thousands of previously undescribed species—from a yeti crab to a giant spiny lobster—by the time it wraps up later this year.

Most future discoveries, says ornithologist Bruce Beehler of Conservation International, will probably come from remote areas with lots of variation in habitat—for instance, where a mountain range meets a river basin. In such terrain populations of organisms tend to get separated from one another and develop adaptations to survive in their new territory. Beehler says to expect discoveries from the eastern slope of the Andes in South America, the Congo basin in West Africa and the eastern Himalayas in Asia. On a 2005 helicopter expedition in New Guinea, he and Helgen discovered an entire "lost world" of new species deep in the Foja Mountains; after two return visits, the team has cataloged more than 70 new species, including a type of wallaby and a gecko. They now have their eyes on another mountainous area of western New Guinea they call "the Bird's Neck." They just need to figure out how to get there.

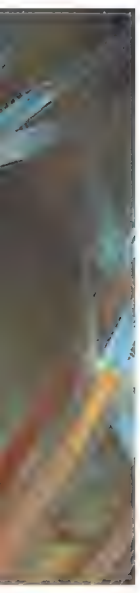
But new species also turn up in less exotic places—a slender salamander 30 miles from Los Angeles, or a new genus of tree that grows up to 130 feet tall two hours from Sydney, Australia. And Helgen notes that two out of three new mammal species are discovered in museum collection cabinets.

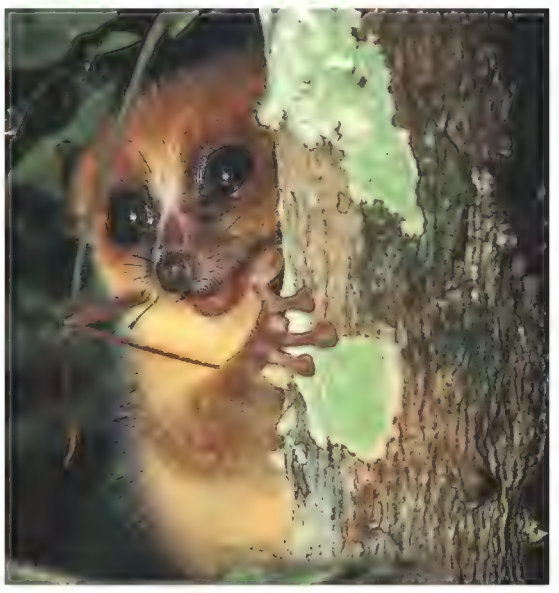
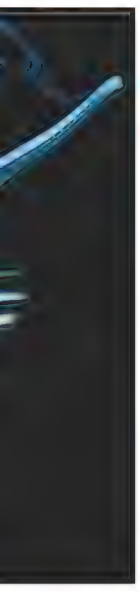
That's partly because genetic analysis is revealing "cryptic species," creatures that look alike to us but not to each other. For instance, scientists now believe that giraffes, currently clas-

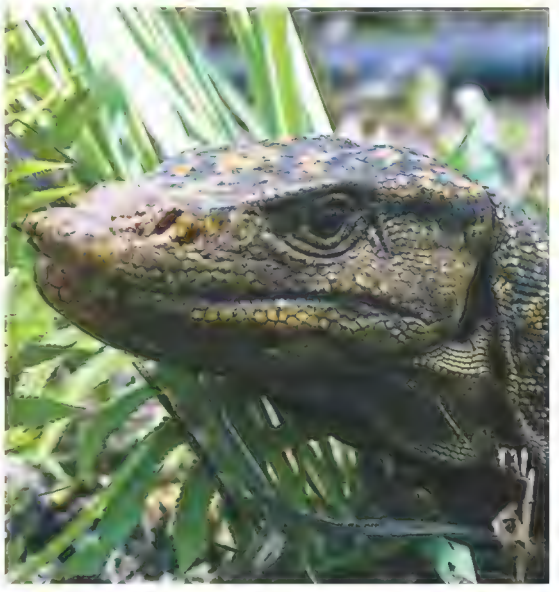


TOP ROW FROM LEFT: chameleon (*Kinyongia magomberae*), Tanzania; Satomi's pygmy seahorse (*Hippocampus satomiae*), Indonesia; color-changing frog (*Oreophryne ezra*), Papua New Guinea; dragon millipede (*Desmoxytes purposa*), Thailand; Goodwin's mouse lemur (*Microcebus lehilahystara*), Madagascar. **SECOND ROW:** salamander (*Bolitoglossa* sp.), Ecuador; deep-sea worm (*Swima bombiviridis*), Monterey Bay; scops owl (*Otus thilohoffmani*), Sri Lanka; mouse (*Mus cypriacus*), Cyprus; monitor lizard (*Varanus bitatawa*), Philippines. **THIRD ROW:** wallaby (*Dorcopsulus* sp.), Indonesia; tiger-striped pit viper (*Cryptelytrops honsonensis*), Vietnam; sea spider (in the class Pycnogonida), Antarctica; jellyfish (*Stellamedusa ventana*), eastern Pacific Ocean; blue diamond impatiens (*Impatiens namchabarwensis*), Tibet. **FOURTH ROW:** striped rabbit (*Nesolagus timminsi*), Vietnam; wild banana (*Musa rubinea*), Myanmar; limestone leaf warbler (*Phylloscopus calciatilis*), Laos; jumping spider (*Orthus* sp.), Papua New Guinea; frog (*Litoria* sp.), Papua New Guinea.





ANDREW R. MARSHALL; TAKAKO UNO; FRED KRAUS / BISHOP MUSEUM / ASIH; GREATER MEKONG PROGRAMME / WWF INTERNATIONAL; JÖRN KÖHLER; JESSICA DEICHMANN / CONSERVATION INTERNATIONAL; STEVEN HADDOCK / MBARI; GEHAN DE SILVA WIJEYERATNE; CNRS PHOTOTHÈQUE / ORTH, ANNE-MARIE; JOSEPH BROWN / UNIVERSITY OF KANSAS; TIM LAMAN / NATIONAL GEOGRAPHIC STOCK; LEE AQUARIUM RESEARCH INSTITUTE (MBARI); ELAYNE TAKEMOTO / WWF NEPAL; TRINH VIET CUONG / FFI / WWF; MARKKU HAKKINEN / WWF GREATER MEKONG; PETER DAVIDSON; WAYNE MADDISON / CONSERVATION INTERNATIONAL; STEPHEN J. RICHARDS

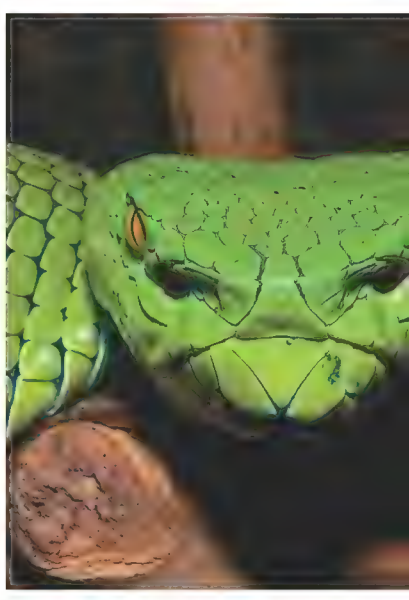
sified as a single species, really belong to six or more species, some of which might not have bred together in the wild for more than a million years. Likewise, researchers recently took a closer look at a bat that ranges across much of South America and found genetic evidence suggesting that some identical-looking bats are different species. Such genetic differences can open the eyes of field biologists to previously unsuspected traits. "Maybe it's scent, a sound, a pheromone, something that doesn't get preserved in a museum," says Elizabeth Clare of the University of Guelph in Ontario, a co-author of the bat study.

Why should we care? If you've seen one look-alike bat, or rat, or parasitic wasp, haven't you seen them all? In fact, our own lives sometimes depend on recognizing the subtle differences. For instance, South American night monkeys of the genus *Aotus* used to be regarded as a single species. Then a primatologist found that they really belong to nine separate species that differ in their susceptibility to malaria. That mattered because scientists relied on *Aotus* as a laboratory animal for malaria studies—and did not realize they could be getting bogus results, and putting human lives in peril, by inadvertently testing malaria treatments on a species that might not be vulnerable to the disease in the first place.

NO. 8
IT'S CURTAINS FOR THE WORLD'S RAREST DOLPHIN, "THE GODDESS OF THE YANGTZE."

But what really drives scientists to the far ends of the earth in search of new species is something far less pragmatic. Visiting New Caledonia as a young man, the evolutionist and ant taxonomist E. O. Wilson realized that "not just the ants but everything I saw, every species of plant and animal, was new to me." Years later, the memory made him confess: "I am a neophile, an inordinate lover of the new, of diversity for its own sake." His greatest desire was to live in a place "teeming with new life forms," wrote Wilson, now 81. All he wanted was "not years but centuries of time" to take its measure.

RICHARD CONNIFF's The Species Seekers *will be out this fall.*



TOP ROW FROM LEFT: gray-faced sengi (*Rhynchocyon udzungwensis*), Tanzania; spider (*Cerbalus aravensis*), Israel; olive-backed forest robin (*Stiphrornis pyrrholaemus*), Gabon; woody vine (*Solanum sanchez-vegae*), Peru. **SECOND ROW:** tree frog (*Nyctimystes* sp.), Papua New Guinea; deep-sea coral (*Gersemia juliepackardae*), eastern Pacific Ocean; stripe-faced fruit bat (*Styloctenium mindorensis*), Philippines; amphipod crustacean (*Epimeria* sp.), Antarctica. **THIRD ROW:** orange-spotted snakehead (*Channa aurantimaculata*), India; Bosavi woolly rat (*Mallomys* sp.), Papua New Guinea; bryozoan (*Microporella klugei*), north of the Arctic Circle; Odessa barb (*Puntius padamya*), Myanmar. **FOURTH ROW:** jumping spider (*Uroballus* sp.), Papua New Guinea; Gumprechts green pit viper (*Trimeresurus gumprechti*), Thailand; patch-nosed salamander (*Urspelerpes brucei*), the U.S. state of Georgia; katydid (*Teraconcha* sp.), Ghana.

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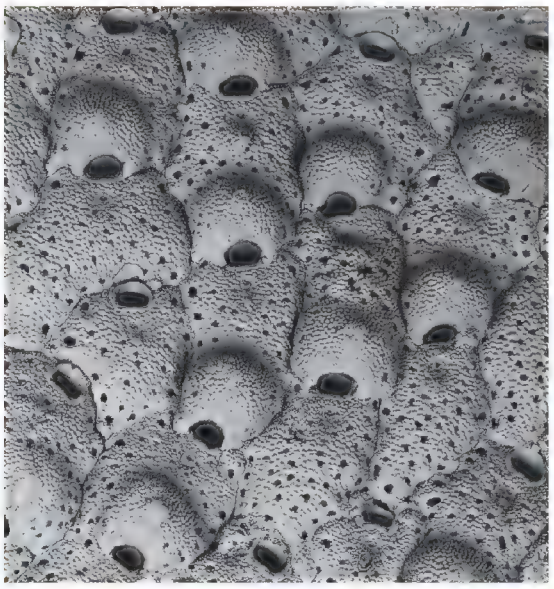

FAREWELL

While species are being discovered around the world, the International Union for Conservation of Nature estimates that one-eighth of all bird species, one-fifth of mammal species and one-third of amphibian species are at risk of extinction. These five are among the most likely to vanish within the next 40 years. ERICA R. HENDRY

RABB'S FRINGE-LIMBED TREEFROG *Ecnomiohyla rabborum*

LOCATION: Panama

ESTIMATED NUMBER IN WILD: One

The big-footed frogs have been devastated by a fungal disease that swept into the area in 2006. Scientists know of only one in the wild, identified by its call. Some live in captivity but have not bred.

PLOUGHSHARE TORTOISE *Astrochelys yniphora*

LOCATION: Madagascar

NUMBER: 400

Confined to five small, unconnected areas, the tortoises are "nearly certain to go extinct within the next 30 years," according to the Wildlife Conservation Society. A fragmented habitat limits breeding, and poachers take them for the illegal pet trade.

HIROLA *Damaliscus hunteri*

LOCATION: Kenya-Somalia border

NUMBER: 600

The population has steadily declined because of disease, drought and predators. Cattle farmers have taken over much of the antelope's habitat, and poaching continues in both countries.

BAIJI *Lipotes vexillifer*

LOCATION: China

NUMBER: Unknown

Scientists declared the dolphin extinct in 2006 after a survey of the Yangtze River failed to yield a single one, but there has since been an unconfirmed sighting. Dams and water pollution have eliminated or damaged the animal's habitat.

THE CAT BA LANGUR *Trachypithecus poliocephalus*

LOCATION: Cat Ba Island, Vietnam

NUMBER: 59

They are hunted for "monkey balm," a traditional medicine. Most surviving langurs are females in isolated groups with little access to males.

NEW SPECIES: FRANCESO ROVERO / CALIFORNIA ACADEMY OF SCIENCES; YAEL OLEK / UNIVERSITY OF HAIFA; CARLTON WARD JR.; ASUNCIÓN CANO / SAN MARCO UNIVERSITY; STEPHEN J. RICHARDS; MBARI; HARVEY GARCIA; CÉDRIC D'UDEKEM D'ACOZ / ALFRED WEGENER INSTITUTE FOR POLAR AND MARINE RESEARCH; ANDERS LINDERSSON / WWF NEPAL; JONNY KEELING / BBC; PIOTR KUKLINSKI / INSTITUTE OF OCEANOLOGY, POLISH ACADEMY OF SCIENCES, SOPOT; N. HEPWORTH; WAYNE MADDISON / CONSERVATION INTERNATIONAL; GREATER MEKONG PROGRAMME / WWF INTERNATIONAL; BILL PETERMAN / UNIVERSITY OF GEORGIA; PIOTR NASKRECKI; FAREWELL: BRAD WILSON / IUCN; NICK GARBUTT / WWW.NHPA.CO.UK; MARK NEWMAN / FLPA / MINDEN PICTURES (CAPTIVE); MARK CARWARDINE / NATUREPL.COM (CAPTIVE); SEACOLOGY (WWW.SEACOLOGY.ORG)

FARMS WILL GO TO TOWN

Grow fruits and vegetables in urban towers? Advocates give a green thumbs up BY T. A. FRAIL

MORE PEOPLE THAN EVER ARE GROWING FOOD IN CITIES, which happen to be where most of the world's people now live. In windowsills, on rooftops and in community gardens, they're burying seeds in Havana, Kinshasa and Hanoi—and in Chicago, Milwaukee and Atlanta. Novella Carpenter's 2009 memoir, *Farm City*, trumpets the value of raising chickens, pigs and bees—in Oakland.

Urban farming is a response to a variety of pressures. Large parts of the developing world are facing shortages of water and arable land, the U.N. Food and Agriculture Organization says. Governments and other sponsors have supported urban food-growing projects in Cuba, Colombia, Botswana and Egypt. In the developed world, small-scale urban farms are seen as an antidote to industrialized agriculture's excesses, including chemical fertilizers that pollute waterways and the high costs, both monetary and environmental, of transporting food to urban markets.

Dickson Despommier, a professor of environmental health sciences at Columbia University, has proposed "vertical farming": growing food—including fish and poultry—in urban buildings as tall as 30 stories and covering a city block. In his vision, you could eliminate the need for soil by growing plants hydroponically (in a liquid) or aeroponically (in the air). You'd reduce water use and end runoff by recycling water in a closed irrigation system. Transportation costs would be next to nil.

NO. 9
JOINING FORCES, FARMERS AND CITY DWELLERS WILL PLANT SPINACH IN TALL BUILDINGS.

Such a high-rise farm has not yet been built. But in Devon, England, the Paignton Zoo has maintained a hydroponic, controlled-irrigation garden for several months. The yield from its 11,000-odd leafy vegetable plants—lettuce, spinach, herbs—is fed to the animals. The garden takes up 1,000 square feet in a greenhouse, about one-twentieth of what it would require in a field. Kevin Frediani, the zoo's curator of plants, says its key technology, a system of mobile nine-foot-high racks that help ensure the plants are properly fed and exposed to light and air, could be scaled up.

The maker of those racks, Britain-based Valcent Products Inc., says it is speaking to potential customers in more than 30 countries. "Agriculture has many problems, and it needs to have different methods as part of its armory of solutions," says Valcent spokesman Tom Bentley. "Vertical farming will be part of that."

T. A. FRAIL *is a senior editor at* SMITHSONIAN.

A "living skyscraper," as rendered by designer Blake Kurasek, could rise from the shallows of Lake Michigan and serve Chicago.

BLAKE KURASEK / GRADUATE SCHOOL OF ARCHITECTURE, UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

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POPULATIONS

40 THINGS TO KNOW

"Much of the innovation reshaping our world comes from the private sector," President Obama writes.

WHY I'M OPTIMISTIC

Americans' restless searching for solutions bodes well for the future

BY BARACK OBAMA

THERE IS, OF COURSE, NO WAY OF KNOWING WHAT NEW challenges and new possibilities will emerge over the next 40 years. There is no way of knowing how life will be different in 2050. But if we do what's required in our own time, I am confident the future will be brighter for our people, and our country.

Such confidence stems largely from the genius of America. From our earliest days, we have reimagined and remade ourselves again and again. Colonists in the 1750s couldn't have imagined that 40 years later, they would be living in a nation, independent of empire. Farmers in the first decades of the 19th century couldn't have imagined that 40 years later, their continent would be crisscrossed by a railroad linking Eastern ports to Western markets. More recently, my parents' generation couldn't have imagined, as children, a world transformed by the Internet.

That we have constantly transformed ourselves is a testament to our people—our entrepreneurs and innovators, scientists and engineers, dreamers, tinkerers and makers of things. It is also a testament to our times. For thousands of years, people on every continent lived much the same way their parents and grandparents lived. But over the past few centuries, the pace of change has steadily picked up, and today new technologies and innovations are coming faster than ever, replacing the ones that preceded them.

Much of the innovation reshaping our world comes from the private sector. Rightly so. Our businesses have always been a force for dynamism. But there is also a role for government in helping us adapt to—and shape—the future. From the Erie Canal to space exploration to what became the Internet, we've always come together to spur transformation. That is a commitment my administration has upheld. Over the past year, we've made the largest investment in basic research funding in history; it's an investment with the potential to spark new technologies, new treatments and new breakthroughs we can't foresee.

NO. 10
THE NATION WILL MEET THE TESTS AND SEIZE THE OPPORTUNITIES OF THE CENTURY AHEAD.

Beyond our investments in basic research, I believe a greater focus in two areas—education and energy—can help fortify America to meet the tests and seize the opportunities of the century that lies ahead. In the 19th century, we built land-grant institutions to prepare an agricultural nation for an industrializing world. In the 20th century, we sent a generation of veterans to college on the G.I. Bill, laying the groundwork for our great middle class and decades of prosperity. Today, a similar commitment is required, not only to prepare our kids to outcompete workers around the world, but to prepare America to outcompete nations around the world. That is why we've taken steps to increase Pell Grants and ensure they keep pace with inflation, making college—and advanced training—more affordable for countless students. That's why we ended a status quo that handed out billions of dollars to banks to act as unnecessary middlemen in administering student loans, and made the repayment of loans more manageable for students so they don't graduate with crushing debts. And that's why we're undertaking a Race to the Top in America's schools, challenging states to compete for tax dollars to help them deliver better results in the classroom.

Just as we are rising to meet our education challenge, we must rise to meet our energy challenge. From Franklin's experiments with lightning to the research labs of today, we've always sought out new forms of energy. As I write this, the tragic oil spill along the Gulf Coast is threatening livelihoods and America's precious natural bounty, making the need for clean energy all the more urgent. Meanwhile, other nations—from China to Germany—are racing to build a clean energy future, recognizing that it holds the key to new jobs and new industries in this young century.

If we hope to continue leading the global economy, America must place first in that race. That's why we're making the most significant investment in clean energy in history, offering grants to companies that produce wind turbines and solar panels, helping us double renewable energy production in the coming years. That's why we've helped forge one historic agreement—and are on track to produce a second—to dramatically increase the fuel efficiency of cars and trucks. And that's why I'll keep fighting for comprehensive energy and climate legislation—to unleash the potential of clean energy for our economy, our security and our environment.

When I was sworn into office, I had a chance to request objects from some of America's finest museums to put on display in the White House. One of my requests was for patent models from the Smithsonian National Museum of American History: Samuel Morse's 1849 design for a telegraph register; Henry Williams' 1877 design for a steamboat wheel; and John A. Peer's 1874 design for a gear-cutting machine.

They rest on the bookshelves in the Oval Office, and I see them every day. For me, they are a reminder of what has always defined America's people: our spirit; a restless searching for the right solution to any problem; an inclination to dream big dreams, and an insistence on making those dreams come true; an enduring faith, even in the darkest hours, that brighter days lie ahead. That is the genius of America. And that's why, even though I can't predict what will happen over the next 40 years, I am—and always will be—full of hope about what the future holds.

BARACK OBAMA *is the president of the United States.*

ICON ILLUSTRATIONS: STEVEN NOBLE; JONATHAN ERNST / REUTERS

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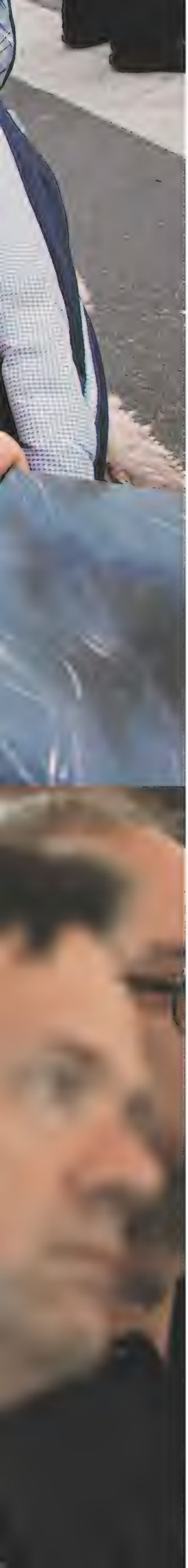


POPULATIONS 40 THINGS TO KNOW

READY SET GROW

The U.S. population will expand by 100 million over the next 40 years. That's a good thing, the author argues

BY JOEL KOTKIN

ESTIMATES OF THE UNITED STATES POPULATION at the middle of the 21st century vary, from the U.N.'s 404 million to the U.S. Census Bureau's 422 to 458 million. To develop a snapshot of the nation at 2050, particularly its astonishing diversity and youthfulness, I use the nice round number of 400 million people, or roughly 100 million more than we have today.

The United States is also expected to grow somewhat older. The portion of the population that is currently at least 65 years old—13 percent—is expected to reach about 20 percent by 2050. This "graying of America" has helped convince some commentators of the nation's declining eminence. For example, an essay by international relations expert Parag Khanna envisions a "shrunken America" lucky to eke out a meager existence between a "triumphant China" and a "retooled Europe." Morris Berman, a cultural historian, says America "is running on empty."

But even as the baby boomers age, the population of working and young people is also expected to keep rising, in contrast to most other advanced nations. America's relatively high fertility rate—the number of children a woman is expected to have in her lifetime—hit 2.1 in 2006, with 4.3 million total births, the highest levels in 45 years, thanks largely to recent immigrants, who tend to have more children than residents whose families have been in the United States for several generations. Moreover, the nation is on the verge of a baby boomlet, when the children of the original boomers have children of their own.

Between 2000 and 2050, census data suggest, the U.S. 15-to-64 age group is expected to grow 42 percent. In contrast, because of falling fertility rates, the number of young and working-age people is expected to *decline* elsewhere: by 10 percent in China, 25 percent in Europe, 30 percent in South Korea and more than 40 percent in Japan.

Within the next four decades most of the developed countries in Europe and East Asia will become veritable old-age homes: a third or more of their populations will be over 65. By then, the United States is likely to have more than 350 million people *under* 65.

By 2050 minorities (above and opposite top: Latinos in New York City) will be half of the U.S. population, seniors (opposite bottom) one-fifth.

THE PROSPECT OF an additional 100 million Americans by 2050

worries some environmentalists. A few have joined traditionally conservative xenophobes and anti-immigration activists in calling for a national policy to slow population growth by severely limiting immigration. The U.S. fertility rate—50 percent higher than that of Russia, Germany and Japan and well above that of China, Italy, Singapore, South Korea and virtually all the rest of Europe—has also prompted criticism.

Colleen Heenan, a feminist author and environmental activist, says Americans who favor larger families are not taking responsibility for "their detrimental contribution" to population growth and "resource shortages." Similarly, Peter Kareiva, the chief scientist at the Nature Conservancy, compared different conservation measures and concluded that not having a child is the most effective way of reducing carbon emissions and becoming an "eco hero."

Such critiques don't seem to take into account that a falling population and a dearth of young people may pose a greater threat to the nation's well-being than population growth. A rapidly declining population could create a society that doesn't have the work force to support the elderly and, overall, is less concerned with the nation's long-term future.

The next surge in growth may be delayed if tough economic times continue, but over time the rise in births, producing a generation slightly larger than the boomers, will add to the work force, boost consumer spending and generate new entrepreneurial businesses. And even with 100 million more people, the United States will be only one-sixth as crowded as Germany is today.

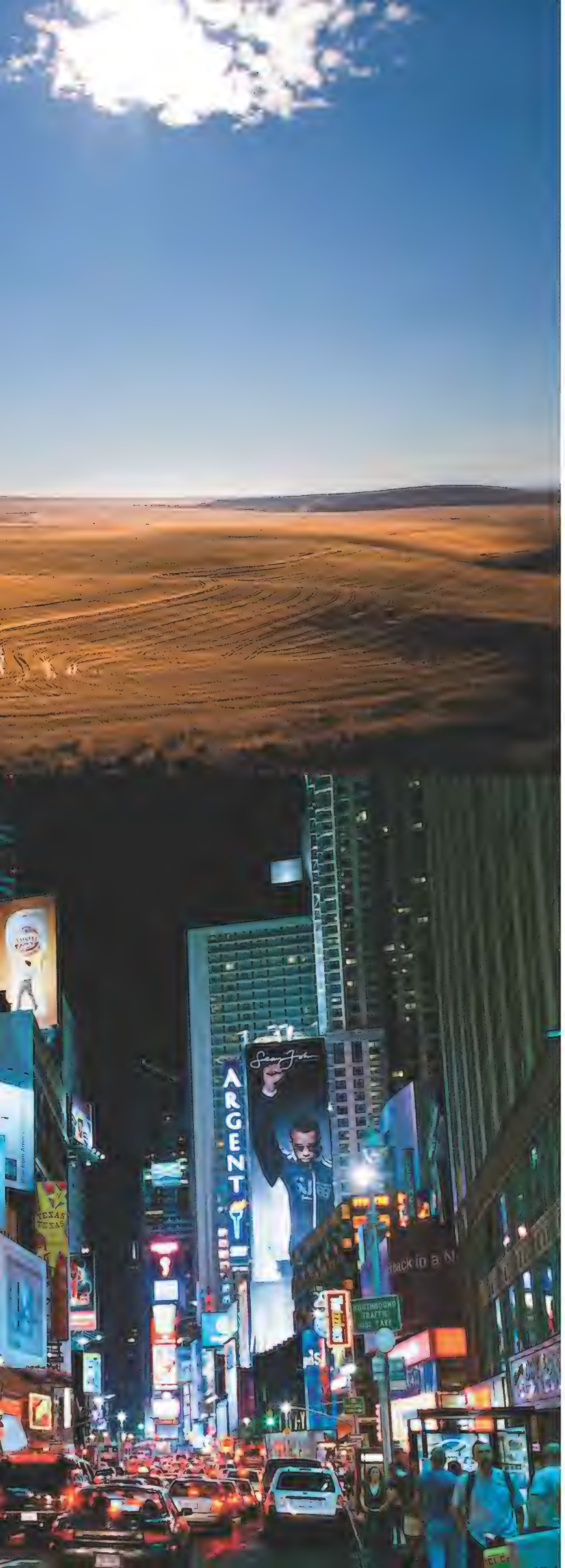
NO. 11
HAVING LOST PEOPLE AND INDUSTRY FOR YEARS, THE HEARTLAND WILL RISE AGAIN.

Immigration will continue to be a major force in U.S. life. The United Nations estimates that two million people a year will move from poorer to developed nations over the next 40 years, and more than half of those will come to the United States, the world's preferred destination for educated, skilled migrants. In 2000, according to the Organisation for Economic Co-operation and Development, an association of 30 democratic, free-market countries, the United States was home to 12.5 million skilled immigrants, equaling the combined total for Germany, France, the United Kingdom, Australia, Canada and Japan.

If recent trends continue, immigrants will play a leading role in our future economy. Between 1990 and 2005, immigrants started one out of four venture-backed public companies. Large American firms are also increasingly led by people with roots in foreign countries, including 15 of the Fortune 100 CEOs in 2007.

For all these reasons, the United States of 2050 will look different from that of today: whites will no longer be in the majority. The U.S. minority population, currently 30 per-

Adapted from *The Next Hundred Million* by Joel Kotkin. © 2010. With the permission of the publisher, The Penguin Press, a member of Penguin Group (USA) Inc.



cent, is expected to exceed 50 percent before 2050. No other advanced, populous country will see such diversity.

In fact, most of America's net population growth will be among its minorities, as well as in a growing mixed-race population. Latino and Asian populations are expected to nearly triple, and the children of immigrants will become more prominent. Today in the United States, 25 percent of children under age 5 are Hispanic; by 2050, that percentage will be almost 40 percent.

Growth places the United States in a radically different position from that of Russia, Japan and Europe. Russia's low birth and high mortality rates suggest its overall population will drop by 30 percent by 2050, to less than a third of the United States'. No wonder Prime Minister Vladimir Putin has spoken of "the serious threat of turning into a decaying nation." While China's population will continue to grow for a while, it may begin to experience decline as early as 2035, first in work force and then in actual population, mostly because of the government's one-child mandate, instituted in 1979 and still in effect. By 2050, 31 percent of China's population will be older than 60. More than 41 percent of Japanese will be that old.

Political prognosticators say China and India pose the greatest challenges to American predominance. But China, like Russia, lacks the basic environmental protections, reliable legal structures, favorable demographics and social resilience of the United States. India, for its part, still has an overwhelmingly impoverished population and suffers from ethnic, religious and regional divisions. The vast majority of the Indian population remains semiliterate and lives in poor rural villages. The United States still produces far more engineers per capita than India or China.

SUBURBIA WILL CONTINUE TO BE a mainstay of American life. Despite criticisms that suburbs are culturally barren and energy-inefficient, most U.S. metropolitan population growth has taken place in suburbia, confounding oft-repeated predictions of its decline.

Some aspects of suburban life—notably long-distance commuting and heavy reliance on fossil fuels—will have to change. The new suburbia will be far more environmentally friendly—what I call "greenurbia." The Internet, wireless phones, video conferencing and other communication technologies will allow more people to work from home: at least one in four or five will do so full time or part time, up from roughly one in six or seven today. Also, the greater use of trees for cooling, more sustainable architecture and less wasteful appliances will make the suburban home of the future far less of a danger to ecological health than in the past. Houses may be smaller—lot sizes are already shrinking as a result of land prices—but they will remain, for the most part, single-family dwellings.

A middle-class migration to uncrowded, affordable regions (top left: a farmhouse in Oregon) may be sparked by the high cost of living in "superstar cities" (bottom left: Times Square).

BRIAN SMALE; PATRICK ZACHMANN / MAGNUM PHOTOS; PP. 60-61 Q. SAKAMAKI / REDUX; CHRISTOPHER FITZGERALD / CANDIDATEPHOTOS.COM; P. 61 MARIO TAMA / GETTY IMAGES

A new landscape may emerge, one that resembles the network of smaller towns characteristic of 19th-century America. The nation's landmass is large enough—about 3 percent is currently urbanized—to accommodate this growth, while still husbanding critical farmland and open space.

In other advanced nations where housing has become both expensive and dense—Japan, Germany, South Korea and Singapore—birthrates have fallen, partly because of the high cost of living, particularly for homes large enough to comfortably raise children. Preserving suburbs may therefore be critical for U.S. demographic vitality.

A 2009 study by the Brookings Institution found that between 1998 and 2006, jobs shifted away from the center and to the periphery in 95 out of 98 leading metropolitan regions—from Dallas and Los Angeles to Chicago and Seattle. Walter Siembab, a planning consultant, calls the process of creating sustainable work environments on the urban periphery "smart sprawl." Super-fuel-efficient cars of the future are likely to spur smart sprawl. They may be a more reasonable way to meet environmental needs than shifting back to the mass-transit-based models of the industrial age; just 5 percent of the U.S. population uses mass transit on a daily basis.

One of the urban legends of the 20th century—espoused by city planners and pundits (and a staple of Hollywood)—is that suburbanites are alienated, autonomous individuals, while city dwellers have a deep connection to their neighborhoods. As the 2001 book *Suburban Nation* puts it, once suburbanites leave the "refuge" of their homes they are reduced to "motorist[s] competing for asphalt."

But suburban residents express a stronger sense of identity and civic involvement than city dwellers. A recent study by Jan Brueckner, a University of California at Irvine economist, found that density does not, as is often assumed, increase social contact between neighbors or raise overall social involvement; compared with residents of high-density urban cores, people in low-den-

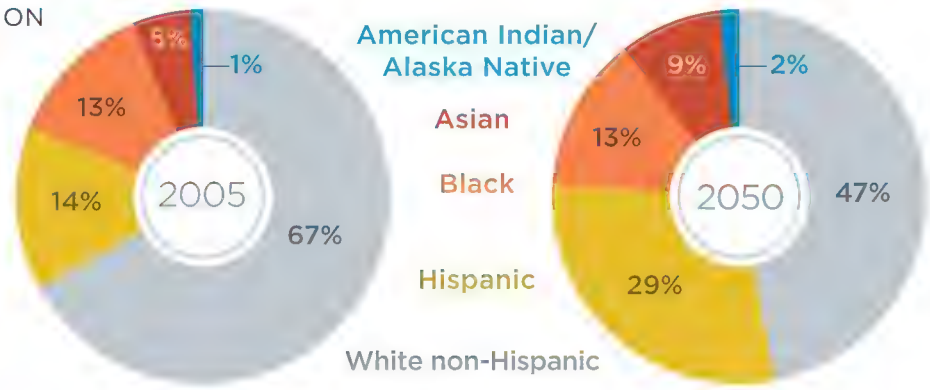
TOMORROW'S POPULATIONS

Experts predict not only a larger U.S. population for 2050 but also an older, more diverse one (below). Global trends (opposite) point to some flux and overall growth to 9.15 billion people

THE UNITED STATES

PERCENT OF TOTAL POPULATION

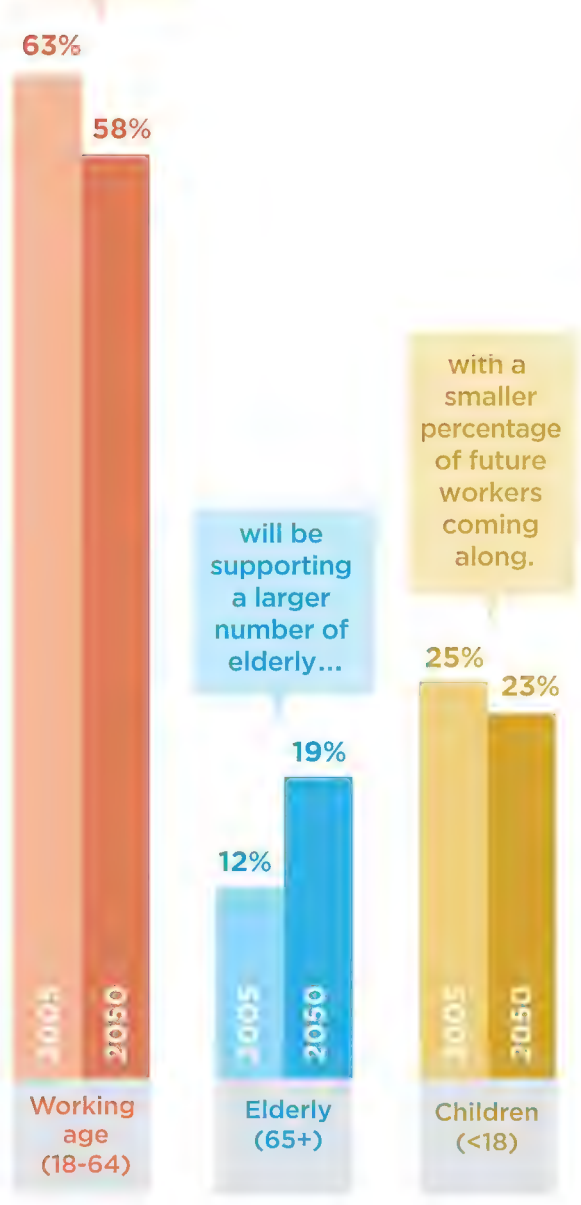
The nation will be more diverse, with today's minorities making up more than half of the total population.



The work force will have more elderly people to support.

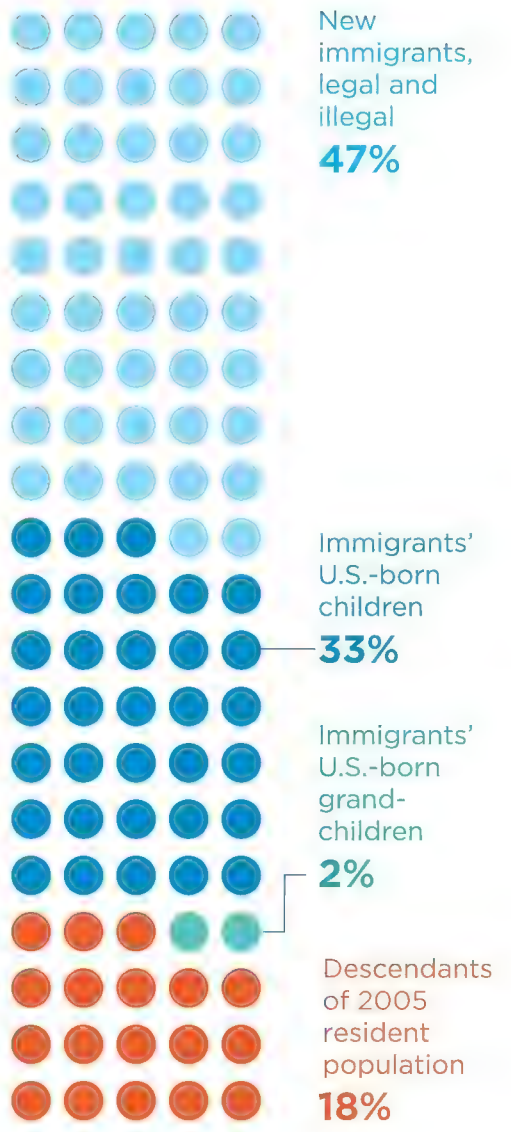
PERCENT OF TOTAL POPULATION

A smaller percentage of workers...



New immigrants and their U.S.-born descendants will account for most U.S. population growth. Predicting future illegal immigration is difficult. In recent years, about 40 percent of new immigrants have been illegal.

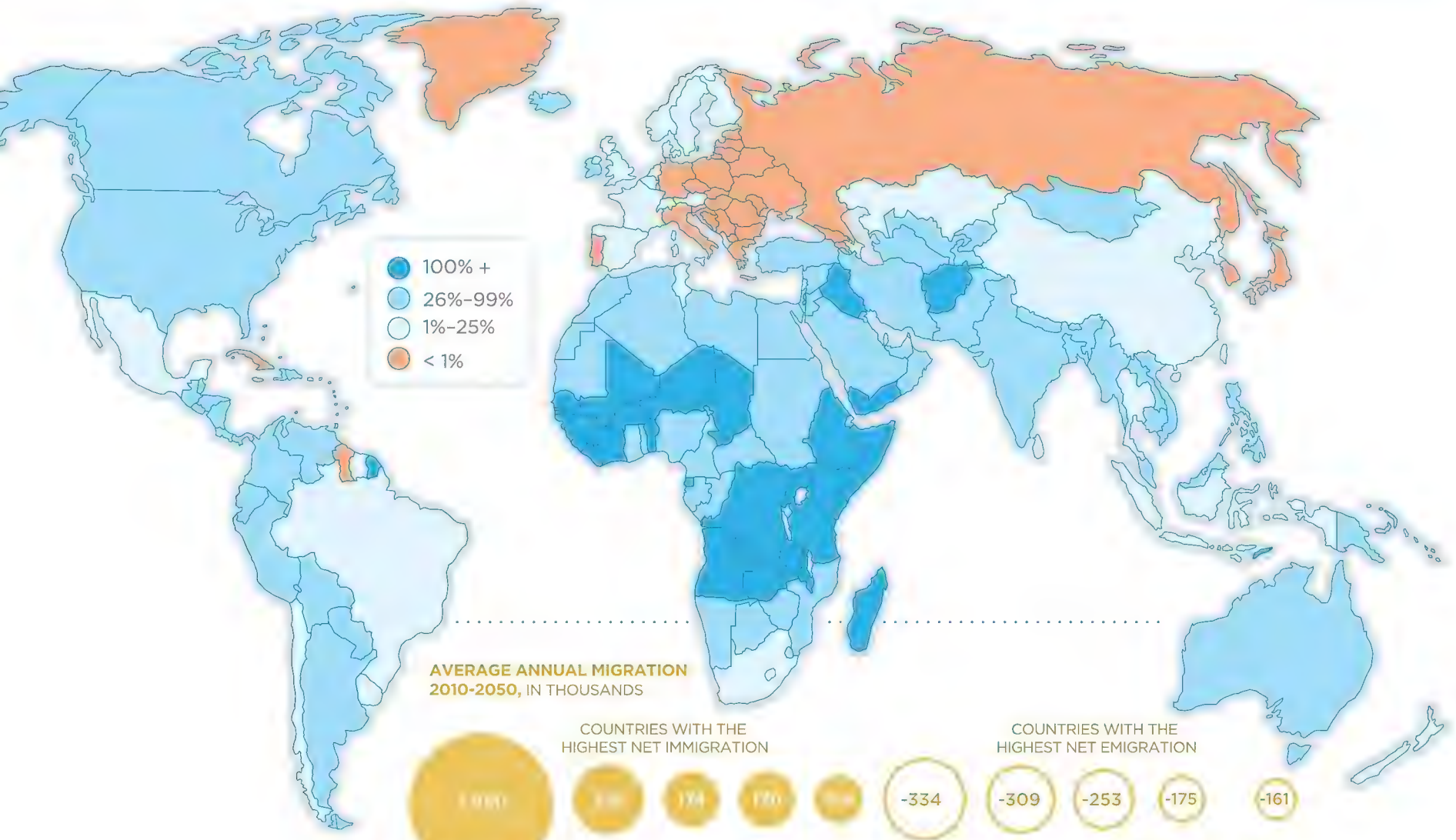
U.S. POPULATION GROWTH 2005-2050



SOURCE: *U.S. POPULATION PROJECTIONS: 2005-2050* / PEW RESEARCH CENTER

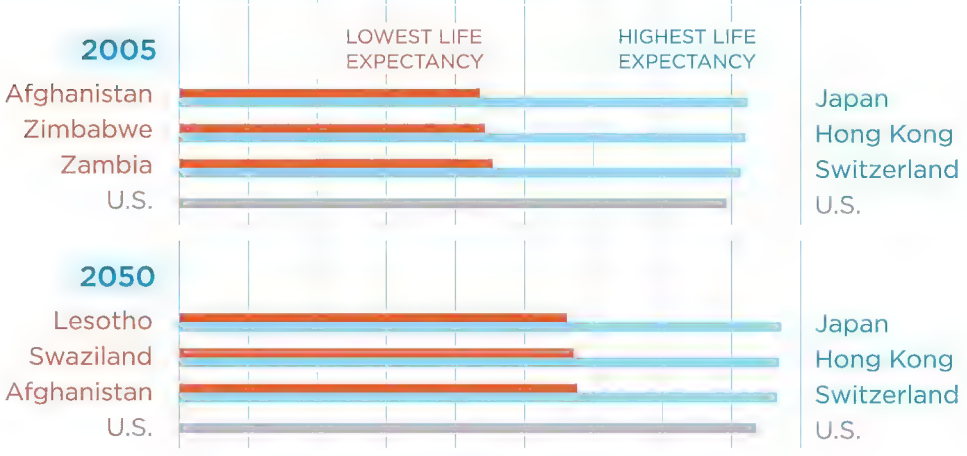
THE WORLD

PERCENT POPULATION CHANGE 2009-2050



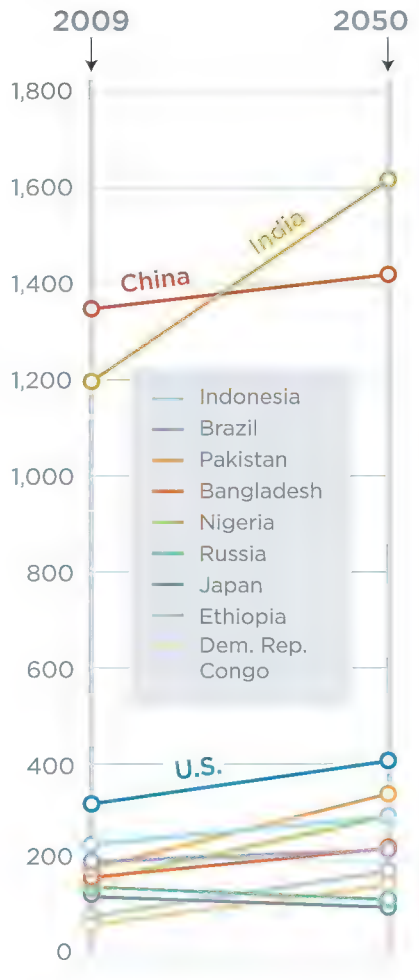
In 2050, median age will range from early 20s to mid 50s, with the worldwide median age being 38.4 years.

Average life expectancy of the top three longest-living populations will increase by 4.6 years, while that of the shortest-living populations will increase by 13.5 years, or 30 percent.



Most populous countries

MILLIONS OF PEOPLE



SOURCE: *POPULATION PROSPECTS: THE 2008 REVISION* / UNITED NATIONS

GRAPHICS BY LINDA ECKSTEIN AND SAMUEL VELASCO FOR 5W INFOGRAPHICS

sity suburbs were 7 percent more likely to talk to their neighbors and 24 percent more likely to belong to a local club.

Suburbs epitomize much of what constitutes the American dream for many people. Minorities, once largely associated with cities, tend to live in the suburbs; in 2008 they were a majority of residents in Texas, New Mexico, California and Hawaii. Nationwide, about 25 percent of suburbanites are minorities; by 2050 immigrants, their children and native-born minorities will become an even more dominant force in shaping suburbia.

The baby boom generation is poised for a large-scale "back to the city" movement, according to many news reports. But Sandra Rosenbloom, a University of Arizona gerontology professor, says roughly three-quarters of retirees in the first bloc of boomers appear to be sticking close to the suburbs, where the vast majority reside. "Everybody in this business wants to talk about the odd person who moves downtown," Rosenbloom observes. "[But] most people retire in place. When they move, they don't move downtown, they move to the fringes."

To be sure, there will be 15 million to 20 million new urban dwellers by 2050. Many will live in what Wharton business professor Joseph Gyourko calls "superstar cities," such as San Francisco, Boston, Manhattan and western Los Angeles—places adapted to business and recreation for the elite and those who work for them. By 2050, Seattle, Portland and Austin could join their ranks.

NO. 12
THE TOP SOCIAL PROBLEM WILL BE FULFILLING THE PROMISE OF UPWARD MOBILITY.

But because these elite cities are becoming too expensive for the middle class, the focus of urban life will shift to cities that are more spread out and, by some standards, less attractive. They're what I call "cities of aspiration," such as Phoenix, Houston, Dallas, Atlanta and Charlotte. They'll facilitate upward mobility, as New York and other great industrial cities once did, and begin to compete with the superstar cities for finance, culture and media industries, and the amenities that typically go along with them. The *Wall Street Journal* noted that commercial success has already turned Houston, once considered a backwater, into "an art mecca."

ONE OF THE LEAST ANTICIPATED developments in the nation's 21st-century geography will be the resurgence of the region often dismissed by coastal dwellers as "flyover country." For the better part of the 20th century, rural and small-town communities declined in percentage of population and in economic importance. In 1940, 43 percent of Americans lived in rural areas; today it's less than 20 percent. But population and cost pressures are destined to resurrect the hinterlands. The Internet has broken the traditional isolation of rural communities, and as mass communication improves, the migration of technology companies, business services and manufacturing firms to the heartland is likely to accelerate.

Small Midwestern cities such as Fargo, North Dakota, have experienced higher than average population and job growth over the past decade. These communities, once depopulating, now boast complex economies based on energy, technology and agriculture. (You can even find good restaurants, boutique hotels and coffeehouses in some towns.) Gary Warren heads Hamilton Telecommunications, a call center and telecommunications-services firm that employs 250 people in Aurora, Nebraska. "There is no sense of dying here," Warren says. "Aurora is all about the future."

Concerns about energy sources and hydrocarbon emissions will also bolster America's interior. The region will be pivotal to the century's most important environmental challenge: the shift to renewable fuels. Recent estimates suggest the United States has the capacity to produce annually more than 1.3 billion dry tons of biomass, or fuels derived from plant materials—enough to displace 30 percent of the current national demand for petroleum fuels. That amount could be produced with only modest changes in land use, agricultural and forest-management practices.

Not since the 19th century, when the heartland was a major source of America's economic, social and cultural su-

Share this story and hear Kotkin at smith.hy.pr/population

CAMERON DAVIDSON / AERIALSTOCK

Businesses (above: a wind farm near Milford, Utah) as well as families are shifting from urban centers to metropolitan-area suburbs, where neighborliness, according to one recent study, is more pronounced than expected (opposite: a Las Vegas-area housing development).

premacy, has the vast continental expanse been set to play so powerful a role in shaping the nation's future.

WHAT THE UNITED STATES DOES WITH its demographic dividend—its relatively young working-age population—is critical. Simply to keep pace with the growing U.S. population, the nation needs to add 125,000 jobs a month, the New America Foundation estimates. Without robust economic growth but with an expanding population, the country will face a massive decline in living standards.

Entrepreneurs, small businesses and self-employed workers will become more common. Between 1980 and 2000 the number of self-employed individuals expanded, to about 15 percent of the work force. More workers will live in an economic environment like that of Hollywood or Silicon Valley, with constant job hopping and changes in alliances among companies.

For much of American history, race has been the greatest barrier to a common vision of community. Race still remains all too synonymous with poverty: considerably higher poverty rates for blacks and Hispanics persist. But the future will most likely see a dimming of economic distinctions based on ethnic origins.

Since 1960, the proportion of African-American households at or below the poverty line ($22,000 annually for a family of four in 2008 dollars) has dropped from 55 to 25 percent, while the black middle class has grown from 15 to 39 percent. From 1980 to 2008, the proportion who are considered prosperous—households making more than $100,000 a year in 2008 dollars—grew by half, to 10.3 percent. Roughly 50 percent more African-Americans live in suburbs now than in 1980; most of those households are middle class, and some are affluent.

The most pressing social problem facing mid-21st-century America will be fulfilling the historic promise of upward mobility. In recent decades certain high-end occupation incomes grew rapidly, while wages for lower-income and middle-class workers stagnated. Even after the 2008 economic downturn, largely brought on by Wall Street, it was primarily middle-class homeowners and jobholders who bore the brunt, sometimes losing their residences. Most disturbingly, the rate of upward mobility has stagnated overall, as wages have largely failed to keep up with the cost of living. It is no easier for poor and working-class people to move up the socio-economic ladder today than it was in the 1970s; in some ways, it's more difficult. The income of college-educated younger people, adjusted for inflation, has been in decline since 2000.

To reverse these trends, I think Americans will need to attend to the nation's basic investments and industries, including manufacturing, energy and agriculture. This runs counter to the fashionable assertion that the American future can be built around a handful of high-end creative jobs and will not require reviving the old industrial economy.

A more competitive and environmentally sustainable America will rely on technology. Fortunately, no nation has been more prodigious in its ability to apply new methods and techniques to solve fundamental problems; the term "technology" was invented in America in 1829. New energy finds, unconventional fuel sources and advanced technology are likely to ameliorate the long-prophesied energy catastrophe. And technology can ease or even reverse the environmental costs of growth. With a population of 300 million, the United States has cleaner air and water now than 40 years ago, when the population was 200 million.

The America of 2050 will most likely remain the one truly transcendent superpower in terms of society, technology and culture. It will rely on what has been called America's "civil religion"—its ability to forge a unique common national culture amid great diversity of people and place. We have no reason to lose faith in the possibilities of the future.

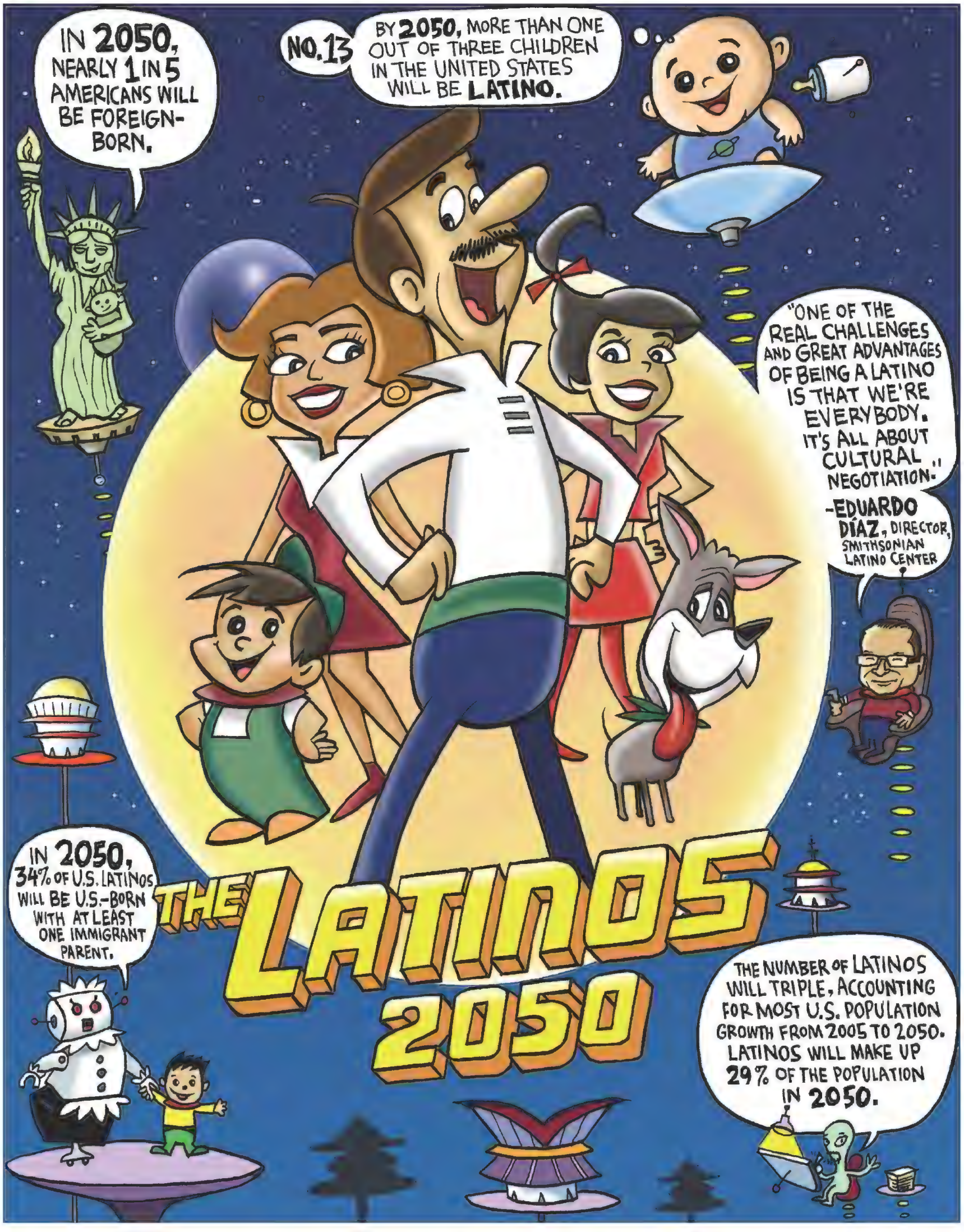
CAMERON DAVIDSON / COURTESY OF CLIPPER WINDPOWER

POPULATIONS

40 THINGS TO KNOW

LOS JETSONS

Experts predict the U.S. population will become increasingly diverse, with the greatest gains among Latinos. The Chicano cartoonist **Lalo Alcaraz**, creator of the syndicated "La Cucaracha" comic strip and illustrator of the book *Latino USA*, reinterprets a now-classic vision of mid-21st-century life


IN 2050, NEARLY 1 IN 5 AMERICANS WILL BE FOREIGN-BORN.
NO.13
BY 2050, MORE THAN ONE OUT OF THREE CHILDREN IN THE UNITED STATES WILL BE LATINO.
"ONE OF THE REAL CHALLENGES AND GREAT ADVANTAGES OF BEING A LATINO IS THAT WE'RE EVERYBODY. IT'S ALL ABOUT CULTURAL NEGOTIATION."
-EDUARDO DÍAZ, DIRECTOR, SMITHSONIAN LATINO CENTER
IN 2050, 34% OF U.S. LATINOS WILL BE U.S.-BORN WITH AT LEAST ONE IMMIGRANT PARENT.
THE LATINOS 2050
THE NUMBER OF LATINOS WILL TRIPLE, ACCOUNTING FOR MOST U.S. POPULATION GROWTH FROM 2005 TO 2050. LATINOS WILL MAKE UP 29% OF THE POPULATION IN 2050.

SOURCE: *U.S. POPULATION PROJECTIONS: 2005-2050* / PEW RESEARCH CENTER

GEORGE FRIEDMAN
THE U.S. STAYS ON TOP

GEORGE FRIEDMAN HOLDS A DOCTORATE *in government from Cornell University and is the founder and chief executive of Stratfor, a geopolitical consulting firm in Austin, Texas. His most recent book is* The Next 100 Years: A Forecast for the 21st Century. *He spoke with Terence Monmaney.*

Commentators have declared the end of American dominance. You disagree. Why?
The 20th century wasn't the American century. In the first half of the century, the United States was a peripheral player—marginal to what was happening. From 1945 to 1991, the United States was caught in a terrific conflict with the Soviet Union. The United States has been the sole global power [only] since 1991, less than 20 years. People say China is emerging as a power. The U.S. economy is roughly three times larger than China's. That's a $10 trillion difference. Twenty-five percent of the world's economic activity happens in the United States. The U.S. Navy controls all the oceans. We are an order of magnitude more powerful than anyone else. Undermining that kind of power can happen, but it normally takes wars, and it certainly takes generations.

NO. 14
WORLD WAR III, INITIALLY INVOLVING THE UNITED STATES, WILL BEGIN IN SPACE IN 2050.

You posit a third world war starting in 2050.
My expectation is we're going to see a fragmentation in China because of internal social stresses, and the weakening of Russia. Three powers are emerging on the periphery of Eurasia. One is Japan, which is truly the center of gravity of Asia; it's the second-largest economy in the world. Unlike China, Japan does not have a billion people living in sub-Saharan-type poverty. It is unified. It has the largest navy in Asia. Second is Turkey, now the 17th-largest economy in the world and the largest Islamic economy. And whenever Islam emerges into a coherent political entity, which it hasn't done for a century, Turkey is almost invariably at its center. Turkey has by far the most powerful and effective military in Europe and is going to be a major Mediterranean power. The third country is Poland. Few people know that Poland is the 21st-largest economy in the world, the 8th-largest in Europe, and by far the most dynamic. It is also a country very much afraid of Germany and Russia. Russia is right now in the process of rebuilding itself. This makes the Poles very uneasy. The Germans are reaching out to the Russians. Poland feels trapped.

Japan is utterly dependent on the sea lanes for the import and export of products. And those sea lanes are controlled by the United States. The United States controls the oceans, and its view is that that is the foundation of its national security. As Japan and Turkey become greater maritime powers, the United States will become hostile toward them. Japan and Turkey each wants to be a maritime power and each sees the U.S. as a threat. Poland has no interest in being a maritime power. It's afraid of Turkey, and interested in the U.S. There's a natural coalition.

The center of gravity of American military power is in space. Everything from navigation to communication to intelligence satellites operate in space. If any power were to knock out the United States, it would have to knock out those assets. If the Japanese and Turks were to take on the United States, that would be the place they would have to strike first, to blind us, to cripple us. I would expect the war to start there. It seems like science fiction, but one wonders how somebody in 1900 would have felt about a description of what World War II was going to be like.

The details may not be as I say—there may be other players, it may not happen in 2050—but every century has a war. The 21st century is not going to be the first century without major warfare.

POLITICAL CALCULUS
The United States, not China, will dominate world affairs, Friedman believes.

LANCE ROSENFIELD

Hear Friedman talk about geopolitics at Smithsonian.com/friedman

POPULATIONS

40 THINGS TO KNOW

AMERICANS LOOK TO 2050

A SMITHSONIAN/Pew poll finds optimism about science and social progress despite worries about the environment and population growth BY T. A. FRAIL ILLUSTRATIONS BY SERGE BLOCH

WITHIN THE NEXT 40 YEARS, MOST AMERICANS BELIEVE, the United States will get the bulk of its energy from sources other than oil. Computers will converse like people. Cancer will be cured, and artificial limbs will outperform natural ones. Astronauts will land on Mars, and ordinary people will travel in space.

But that optimistic outlook on scientific achievement—documented in a nationwide opinion poll conducted by the Pew Research Center and SMITHSONIAN—does not extend to the environment. A small majority of those polled said most of the United States would face severe water shortages by 2050. Six in ten said the oceans would be less healthy than they are now, and seven in ten foresaw a major energy crisis. Overall, fewer than half expected the quality of Earth's environment to improve.

NO. 15
THOUGH USUALLY UPBEAT, MOST AMERICANS ARE DUBIOUS ABOUT THE PLANET'S HEALTH.

"If the U.S. has a national religion, the closest thing to it is faith in technology," said Scott Keeter, director of survey research for the Pew Research Center. But "technology is not seen as a panacea for fixing the environment."

The poll, occasioned by the magazine's 40th anniversary and designed to assess attitudes about the next 40 years, also documented a drop in expectations. Americans remain generally positive, with 64 percent of those surveyed saying they were somewhat or very optimistic about what the next 40 years holds for them and their families; 61 percent said the same about the nation's future. But in a Pew poll taken in May 1999, the questions garnered response rates of 81 percent and 70 percent, respectively.

Of course, the 1999 poll was taken at the height of the high-tech boom and on the eve of a new millennium. Since then, terrorists attacked the United States, the nation has engaged in two wars, the cost of living has outpaced wages and a recession has damaged the economy, among other things.

In the new survey, 58 percent of respondents said a world war would occur in the next four decades, 53 percent said terrorists would attack the United States with nuclear weapons, and the same majority said the nation would be less important in the world than it is now.

The SMITHSONIAN/Pew poll was conducted April 21-26, and included 1,546 adults in the United States reached by residential telephone or cellphone. The margin of error for the total sample is no more than plus or minus 4.5 points.

The documented belief in technological advancement extended from the laboratory (half said an extinct species would be resuscitated through cloning) to outer space (half said evidence of life would be found elsewhere in the universe) to the marketplace (a small majority said gasoline-powered cars would go out of production).

In an exception to the pessimism about the environment, the poll found a ten-point drop in the percentage of respondents who say the earth will get warmer: from 76 percent in 1999 to 66 percent in 2010.

Because the U.S. population is expected to increase by more than 100 million by 2050 (see p. 60), the poll asked about such growth. More than twice as many respondents (42 percent) said it would be more harmful than beneficial (16 percent). And there was ambivalence about immigration. Roughly a third of respondents said legal immigration had to be decreased to keep the economy strong, but a slightly higher proportion said legal immigration had to be kept at current levels; a quarter said it should be increased.

A clear majority expected race relations to improve (68 percent). Even more expected a Hispanic candidate to be elected president of the United States (69 percent). And 89 percent—the largest majority in the entire poll—said a woman would be elected president.

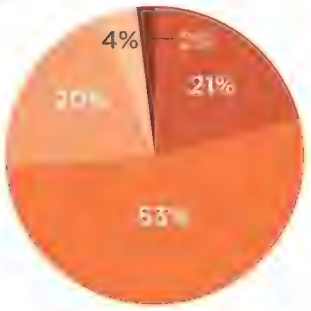
T. A. FRAIL *is a senior editor at* SMITHSONIAN.

SCIENTIFIC ADVANCEMENT

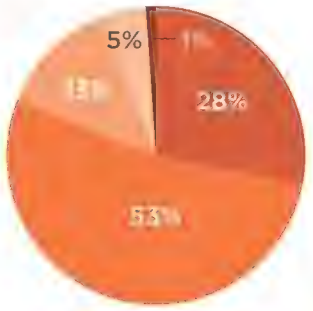
DEFINITELY HAPPEN · PROBABLY HAPPEN · PROBABLY NOT HAPPEN · DEFINITELY NOT HAPPEN · DON'T KNOW/ REFUSED

Over the next 40 years . . .

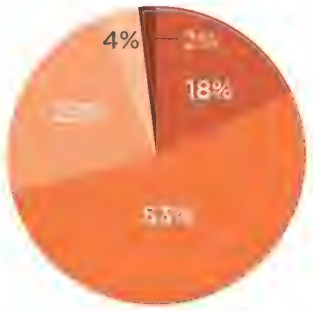
Most of our energy will come from sources other than coal, oil, and gas



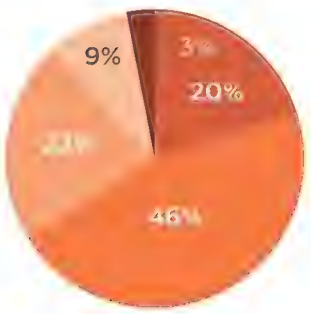
There will be computers that can carry on a conversation just like a human being



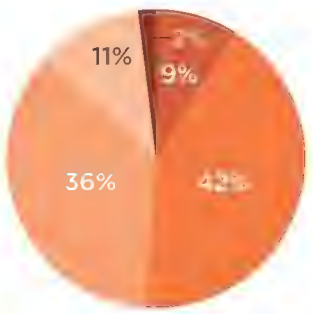
There will be a cure for cancer



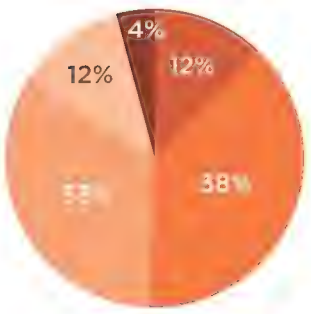
There will be artificial arms and legs that perform better than natural ones



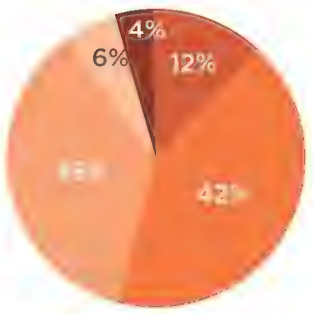
Scientists will bring back an extinct animal species by cloning it



We will find evidence of life elsewhere in the universe



Gasoline-powered cars will no longer be made

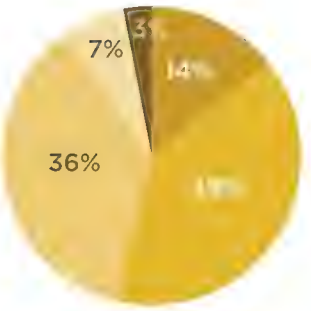


ENVIRONMENTAL PRESSURES

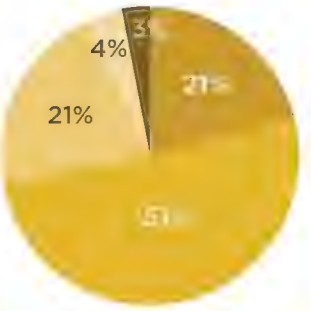
DEFINITELY HAPPEN · PROBABLY HAPPEN · PROBABLY NOT HAPPEN · DEFINITELY NOT HAPPEN · DON'T KNOW/ REFUSED

Over the next 40 years . . .

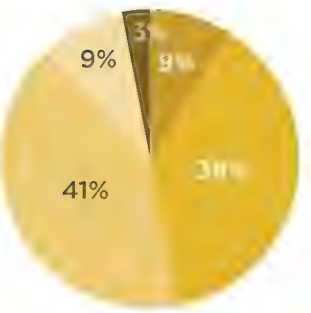
Most of the U.S. will experience severe shortages of fresh water



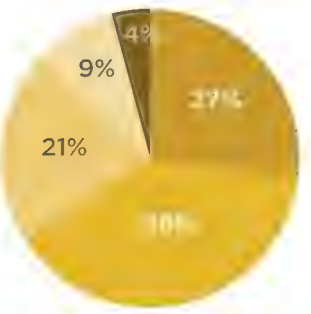
The world will face a major energy crisis



The quality of the earth's environment will improve

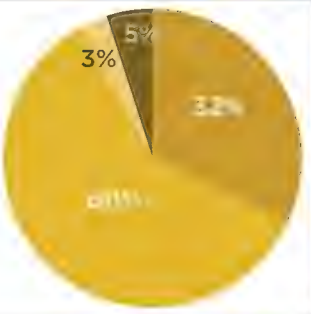


The earth will get warmer



The world's oceans will be . . .

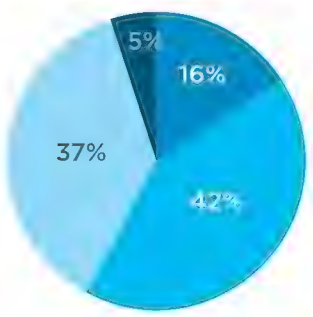
MORE HEALTHY · LESS HEALTHY · NEITHER / NO CHANGE · DON'T KNOW / REFUSED



POPULATION AND SOCIAL CHANGE

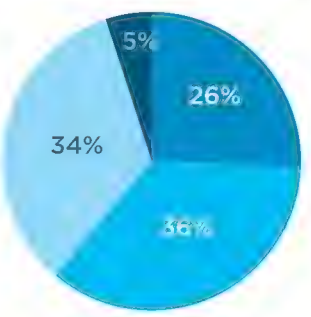
It's estimated that by 2050 the population of the United States will grow by about 100 million. Do you think this population growth will . . .

BENEFIT THE COUNTRY · HARM THE COUNTRY · NEITHER · DON'T KNOW / REFUSED



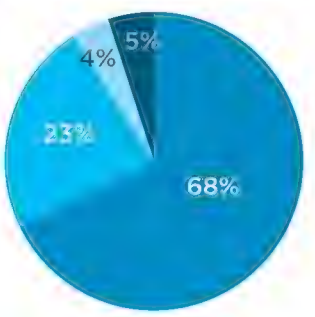
In order to maintain the strength of the U.S. economy over the next 40 years, do you think that *legal* immigration will . . .

NEED TO BE INCREASED · NEED TO BE MAINTAINED · NEED TO BE DECREASED · DON'T KNOW / REFUSED



Thinking ahead 40 years, which is more likely to happen to race relations in the United States?

WILL IMPROVE · WILL GET WORSE · NEITHER / NO CHANGE · DON'T KNOW / REFUSED



CHARTS: SAMUEL VELASCO / 5W INFOGRAPHICS

For more poll results and analysis go to Smithsonian.com/poll

POPULATIONS 40 THINGS TO KNOW Q&A

ROSAMOND NAYLOR FEEDING EVERYONE

SOWING IDEAS

Invest in the poorest of the poor, advises Naylor (in a Stanford greenhouse).

ROSAMOND NAYLOR DIRECTS THE PRO-gram on Food Security and the Environment at Stanford University. An economist by training, she studies the world food economy and sustainable agriculture. Though she says she is deeply worried about climate change and population growth, she described herself as "optimistic" in a conversation with SMITHSONIAN's Amanda Bensen.

By 2050, there will be an estimated nine billion people in the world. Do we have the land and water to feed them?

The arable land area is certainly not enough to meet those demands unless there are major breakthroughs in terms of crop yields. Agriculture and livestock are by far the largest water users in the world. We could have water shortages in a lot of locations. Farmers are going to have to adopt new technologies and crops to be more conservative in their water use. I look to feedbacks in the system. As we start hitting periods of shortages, there is typically more commitment to invest in agriculture to increase productivity. Agricultural markets are dynamic, prices reflect scarcity, and production and consumption can change. I think these dynamics are going to kick in to help.

How do those dynamics work?

As water becomes more scarce, farmers are probably going to switch to crops that are less water-intensive, or that rely on drip irrigation. Or as food prices rise for consumers, maybe they won't eat quite as much meat—especially not as much as we do in the United States—and that will have a feedback on the demand side. We can either adjust and start using land and water more efficiently, or people are going to suffer. A billion people are chronically malnourished and can't afford adequate food right now. If prices go higher, the poor will be among the first to suffer.

NO. 16

IF FARMERS DON'T START SAVING LAND AND WATER, MORE PEOPLE WILL GO HUNGRY.

You mentioned the need to increase crop yields. How?

There's a big gap between farmers' yields and experimental

MARK RICHARDS

yields, that is, the highest that could be achieved. In places like Nebraska, farmers probably are close to the yield ceiling on corn. But for most of the world—Africa, Asia and Latin America—other constraints are keeping farmers from reaching more than 50 percent of the yields we achieve in the United States. Are there incentives to raise crops in more efficient ways? Are there policies that stabilize prices, so farmers invest in crop productivity? Do farmers need better roads to access markets, or credit to buy fertilizer?

Why are so many people hungry?

Persistent poverty. This is really where the population issue comes in, in a nasty way, because it's so hard to take care of everybody. Maybe we're not thinking about it right. Maybe we're thinking that everything will trickle down to these folks—and it's not going to. The global community has only begun to focus on what kind of crop investments you need to reach the poorest of the poor. I think the Gates Foundation, the McKnight Foundation and the Rockefeller Foundation are trying to get at that on a big scale now. They're trying to figure out how to get seed markets going, improve crop marketing for the poor, improve nutrition and make rural economies functional.

How might climate change affect the world's food supply?

What we know for sure is that temperatures are going to increase, which will cause crop productivity to fall after a certain threshold. People say, well, in the United States, if we have warmer temperatures, won't that increase corn production, for example? Yes, up to a point—then there is likely to be a huge drop. Temperature affects evaporation and moisture stress on crops. With the temperature increases that are projected for the next 40 to 50 years, we're going to start to see drop-offs in many parts of the world, particularly in the tropics and subtropics. As the planet warms there may be more moisture in the atmosphere overall, but it won't necessarily fall where you want it, when you want it.

Can you offer an example of increasing food access in a needy population?

We're involved in a project right now in Benin, West Africa, where it rains only three to four months of the year. We're using solar-powered drip irrigation to irrigate small plots of high-value crops for poor farmers. Indigenous legumes that yield more protein and fertilize the soil. Carrots and leafy vegetables that are very nutritious. And the markets are right there in the very poor areas. Farmers are taking their products to market at 5 in the morning and it's all gone by 5:15. It's amazing. In villages where we've been evaluating these techniques, there's been a doubling and tripling of income for families involved, and nutrition has improved throughout the communities.

NO. 17
IN THE FIGHT AGAINST STARVATION, ONE WEAPON WILL BE THE ANCIENT GRAIN FONIO.

Do you think genetically modified crops are part of the solution?

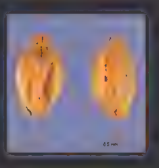
Traits like heat tolerance and drought tolerance in crops are probably going to be induced much more efficiently by genetic engineering than by traditional breeding. I think both approaches have to be part of it.

What about underutilized conventional crops, or so-called orphan crops?

This is why I'm optimistic. There are a lot of crops already out there that are extremely drought and heat tolerant—we've just moved away from them. The agricultural development mentality in the past has been "rice, wheat and corn"—the major staple crops—not "What diversity of crops is more functional, not just ecologically, but economically, for that region?" There needs to be a focus on both nutrition and incomes. The more the global community focuses on food insecurity as being an extremely important issue—and one that will lead to a lot of human suffering if it's not dealt with—I think all sorts of innovative approaches could come in.

NEW FIELDS

Food security experts say these crops, if grown more widely, could help feed the hungry AMANDA BENSEN



FONIO *(Digitaria exilis)*

A type of millet prized in West Africa—the Dogon people of Mali say the universe sprang from a fonio seed—it thrives in poor soil, is rich in amino acid nutrients and provides a tasty base for bread, porridge, pasta and beer.

WHAT'S NEXT? Develop a more efficient way to harvest the tiny seeds.

FORTIFIED CASSAVA *(Manihot esculenta)*

These starchy roots, the source of tapioca, are the primary food for 250 million Africans. Scientists have endowed the traditional plant with new genes that pack the equivalent of a daily multivitamin into each serving.

NEXT: Field trials in Nigeria, where the added nutrients could save up to 30,000 lives a year.

BREADFRUIT *(Artocarpus altilis)*

Known throughout the tropics, this relative of the fig tree bears large fruit rich in carbohydrates, fiber and minerals. It requires less land, water and labor to cultivate than other high-starch crops like maize or rice.

NEXT: Distributing new fast-maturing cultivars to needy farmers.

PIGEON PEA *(Cajanus cajan)*

This protein-rich legume grows well in much of India, China, sub-Saharan Africa and South America. Its deep roots help it resist droughts while improving soil fertility and reducing erosion.

NEXT: Integrating hardier pigeon pea hybrids to diversify maize-based agricultural systems.

GOLDEN RICE

By inserting daffodil genes into a common rice, scientists created a strain enriched with beta carotene, a source of vitamin A. Health experts say millions of malnourished children worldwide could avoid blindness and death from vitamin A deficiency if they ate this genetically modified grain.

NEXT: Cross-breeding experimental golden strains with native rice varieties in needy regions of Southeast Asia.

JOSE HERNANDEZ / USDA-NRCS PLANTS DATABASE; SCIMAT / PHOTO RESEARCHERS, INC.; PALLAVA BAGLA / CORBIS; AJ / IRRI / CORBIS; FREDERICK R. MCCONNAUGHEY / PHOTO RESEARCHERS, INC.; PALLAVA BAGLA / CORBIS

POPULATIONS

40 THINGS TO KNOW

THE AGE OF PEACE

Maturing populations may mean a less violent future for many societies torn by internal conflict **BY CAROLYN O'HARA**

ONE OVERLOOKED BENEFIT OF AGING POPULATIONS may be the prospect of a more peaceful world.

Demographers have found that developing nations with "youth bulges"—more than 40 percent of people between the ages of 15 and 29—are 2.5 times more prone to internal conflict, including terrorism, than countries with fewer young people, largely because of high unemployment combined with youthful exuberance and vulnerability to peers.

"The more young people you have, the more violence you have," says Mark Haas, a political scientist at Duquesne University who has spent the past three years studying how aging patterns among major world powers will affect U.S. security. Between 1970 and 1999, he says, 80 percent of the world's civil conflicts erupted in nations with substantial youth bulges. Today, those bulges are clustered in the Middle East and sub-Saharan Africa, including Nigeria, Saudi Arabia, Uganda, Yemen and Somalia.

But as youth bulges approach middle age, political stability often increases, researchers say. Richard Cincotta, a demographer who consults for the U.S. National Intelligence Council, cites Indonesia: "Political violence has declined in the westward islands," which tend to be older, "while islands to the east, where the age structure is more youthful, remain politically unstable." Cincotta also cites a decrease in political violence in Japan and South Korea—both rocked by student protests in the 1960s and '70s—as their youth bulges dropped below 40 percent. Likewise, waning fertility rates, which have produced a decline in the youthful population in southern India, may have created an environment less supportive of Maoist insurgency groups that are active in the country's northern and eastern states.

"If we know that youth bulges are a big source of violence, including terrorism, it's good news if these youth bulges are receding," Haas says.

Still, older is not always mellower. Not even a maturing population will settle down if accompanying economic gains aren't shared, or if declining fertility rates don't occur uniformly among different groups within a society. Ethnic divisions, in particular, can trump demography. The former Yugoslav republic, notes Cincotta and Haas, experienced years of brutal conflict between relatively mature populations.

In Pakistan and Iraq, the youth bulge won't drop below 40 percent until 2023 and 2030, respectively. Afghanistan is another story. It has one of the world's fastest-growing populations, with more than 50 percent of the population currently 15 to 29 years old. The United Nations does not project that age group to dip below 40 percent before 2050. "The demographic pyramid of Afghanistan right now," Haas says, "is really frightening from a stability point of view."

In Japan (above left), violence has faded as its population has aged. Afghanistan (above right) may continue to experience unrest.

NO. 18
BECAUSE OF ITS "YOUTH BULGE," AFGHANISTAN RISKS TURMOIL FOR ANOTHER 40 YEARS.

CAROLYN O'HARA *lives in Washington, D.C.*

PETER MARLOW / MAGNUM; DARREN MCCOLLESTER / GETTY IMAGES

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40 THINGS TO KNOW

"Bacteria can talk to each other," says Bonnie Bassler (in her Princeton lab). "Not only can they talk, but they are multilingual." And she knows how to speak their languages.

LISTENING TO BACTERIA

By studying microbial communications, Bonnie Bassler has come up with new ways to treat disease BY NATALIE ANGIER

BONNIE BASSLER, HER SHOES KICKED OFF, KNEES UP and socked feet pressed against the rim of the conference room table, watches with an air of droll expectation as a researcher in her world-renowned microbiology laboratory at Princeton University stands up to present his latest experimental results to the other members of her team. Yunzhou Wei is known for his campy presentations, and he does not disappoint. Slides of the cast members of his favorite television crime series flash on the screen and he launches a brief, sportive discussion of the lessons the scientists might extract from the shows: Trust your instincts! But look for evidence, too! Then a far more pressing question arises: which TV character would Bassler want to play? The genius behavioral analyst? No, no, not the "nerdy guy," Bassler grumbles. Well, how about the prim and pretty forensic anthropologist? No, the celebrated scientist's mind is made up. "I want to be her," Bassler says, pointing at Special Agent Jennifer "JJ" Jareau, the Nordic bombshell on the CBS program "Criminal Minds." Case closed, Bassler says. "Let's get back to molecules now."

The character of Jareau suits Bassler remarkably well. Jareau is the communications point person of her group, the media liaison between the FBI and the outside world. Bassler, 48, has been fabulously successful in her career, winning laurels like a MacArthur Foundation "genius" award, membership in the National Academy of Sciences, a coveted position with the Howard Hughes Medical Institute and the presidency of the American Society for Microbiology. And all that can be traced to her deep appreciation for the power of communication. Messaging is the medium in which Bassler shines.

Bassler is at the forefront of the fast-growing field of "quorum sensing," the study of how microbes communicate with each other as they go about building the vast interlocking infrastructure of life on which we macrobes depend. In recent years she and other microbiologists have discovered that bacteria are not the dull solipsists of long-standing reputation, content to merely suck in food, double in size, divide down the middle and repeat ad infinitum, attending to nothing but their obtuse, unicellular selves. Instead, bacteria turn out to

be the original newshounds, glued to their cellphones and Internet chat lines. They converse in a complex chemical language, using molecules to alert one another to who's out there, in what numbers and how best to behave given the present company. Bacteria survey their ranks, they count heads, and if the throng is sufficiently large and like-minded—if there is a quorum—they act. Through chemical signaling, tiny bacterial cells can band together and perform the work of giants. They can compost an elephant, fertilize an oak forest or light up the oceans in the eerie teal glow of bioluminescence. Some bacterial collusions are far less charming and do real harm. Molecular communication allows 600 different species of bacteria to organize themselves into the slimy dental plaque that leads to tooth decay, for example, and it likely enables the nasty pathogens that cause streptococcal pneumonia or bubonic plague to time the release of their toxins for maximum impact on their human hosts.

In deciphering the nuances of bacterial communication, biologists have learned that the lexicons come in two distinct styles: private and public. Every bacterial species has its own dialect, a molecular signature that can be understood only by others of its kind. Bassler made her fame discovering that bacteria also traffic in the second, more universally recognized set of signals that seems to serve as bacterial Esperanto. "Bacteria can talk to each other," she says. "Not only can they talk, but they are multilingual."

NO. 19
GLOWING SQUID WILL INSPIRE SCIENTISTS TO DISCOVER POWERFUL NEW ANTIBIOTICS.

"Bonnie is the champion of bacterial conversations," says Richard Losick, a microbiologist at Harvard University. "This is a field that goes back to the 1970s, but she has re-energized it in a remarkable way."

"Her work is groundbreaking," says Jo Handelsman, a microbiologist at Yale University. "We used to think of bacterial communication as something species specific, but she's really opened up the possibility that interspecies communication is a big part of the quorum-sensing story."

Amusingly enough, the scientist who helped divulge that bacteria are polyglot is herself . . . not. "What do you expect?" she mutters. "I'm an American! I speak English!"

Bassler's foray into microbial idioms is of more than academic interest. The work may well have an impact on what the Centers for Disease Control and Prevention calls one of the "most pressing public health problems" in the world today: antibiotic resistance. In recent years, the overuse of drugs like penicillin to treat childhood earaches, or to inoculate livestock crowded together on factory farms, has spawned the appearance of "superbugs," bacterial strains able to shrug off virtually any of the conventional antibiotics lobbed at them.

Bassler and her peers are guardedly optimistic that their insights into the circuitry of quorum sensing will eventually yield a new, safer generation of antibiotics. Rather than seeking to kill bacteria outright, as current antibiotics do—an approach that readily leads to drug resistance—the novel therapeutics would simply muzzle the molecular messages that induce bacteria to cause disease. Bassler explains the difference between the two approaches this way: "Let's say I'm a bacterium, and you're hitting me with a drug like penicillin that pops the bacterial membrane, but I happen to have a mutation that makes me impervious to that popping effect," she says. "No question about it, I'll have an immediate growth advantage."

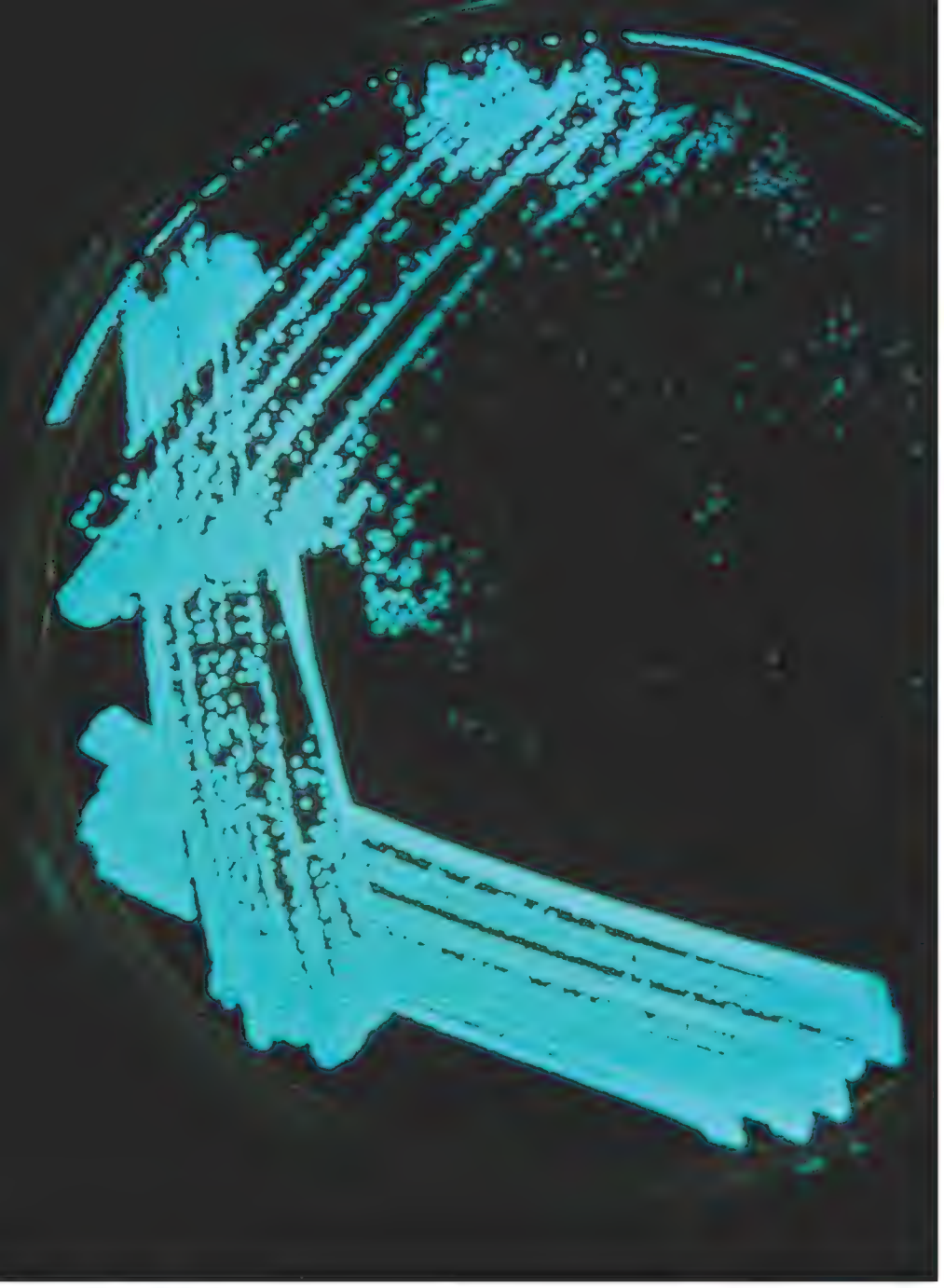
But let's say you are instead using an anti-quorum-sensing drug designed to inhibit bacterial communication, she continues, "and I'm a bacterium with a mutation that makes me immune to the blocker." Great: I'm a microbe that's trying to get in touch with my friends, but because of the blocker, nobody around me is listening. If virulence depends on effective bacterial communication, she says, my lone little mutation will give me no growth advantage at all: "What good does it do me?"

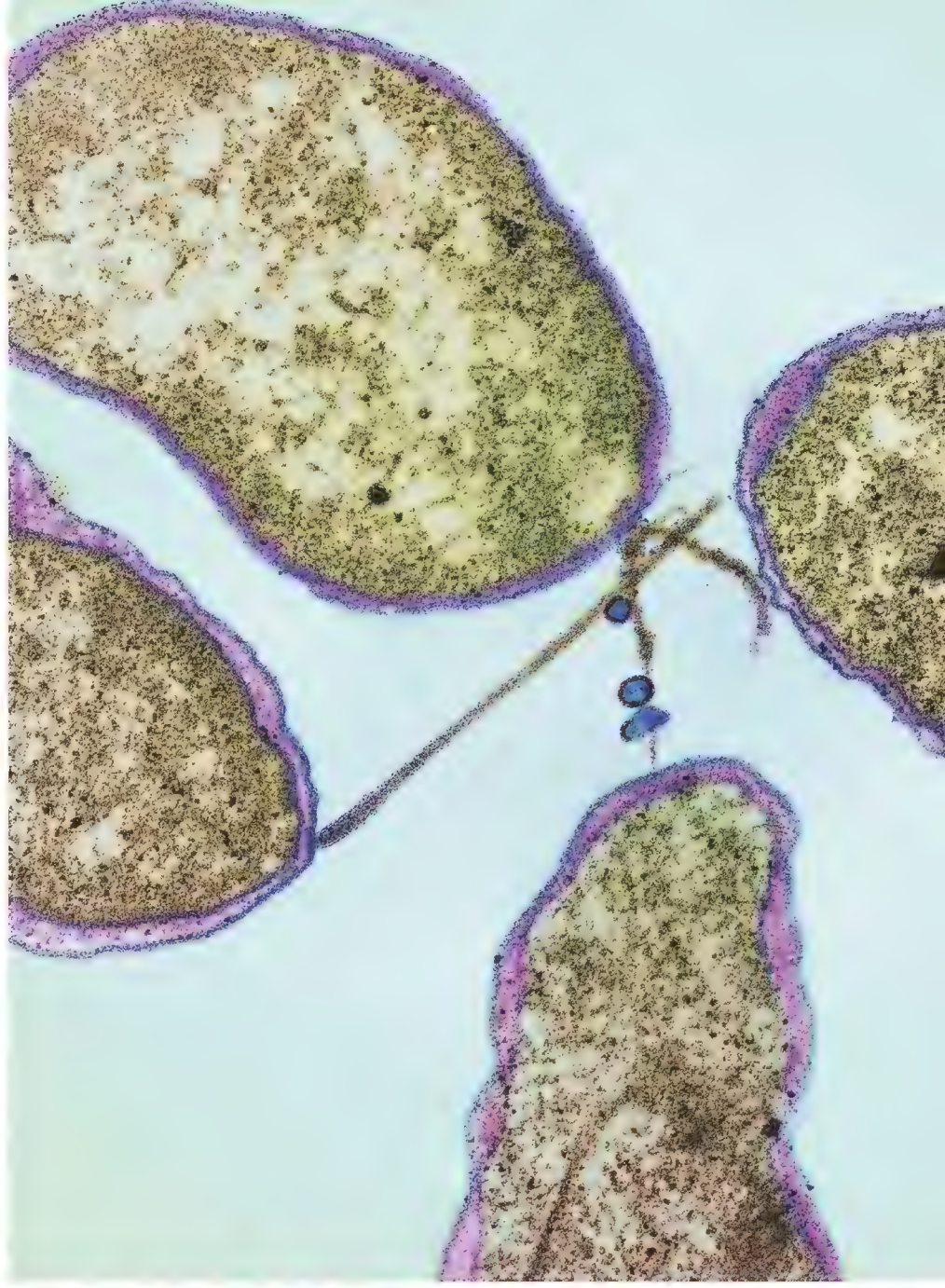
Thomas Silhavy, a microbiologist at Princeton who headed the faculty committee that hired Bassler 16 years ago ("I hit a home run," he says of hiring her. "I hit it out of the park"), is among those with high hopes for eventual spinoffs from quorum-sensing studies. "Of course, it's always a big, multimillion-dollar challenge to turn basic research into an FDA-approved drug," he says. "But I think there's a very real chance this approach will work and give us new tools for intervening in particular diseases." He cites the case of cystic fibrosis, a congenital disorder in which mucus builds up in the lungs and hosts colonies of bacteria called pseudomonas. Infections that normal adults would readily brush away can fulminate for years in cystic fibrosis patients, until one day the chronic turns virulent and overwhelms the body: uncontrollable pseudomonas infection is a major cause of death among people with the disease. Scientists have traced the onset of virulence to the release of quorum-sensing molecules, the chemical messengers that incite the bacteria to begin operating as a group. In theory, Silhavy says, a drug that blocked the pseudomonal calls to mayhem could prove invaluable in the treatment of the devastating disorder.

Bassler and other researchers have identified a number of molecules that disrupt quorum sensing in test-tube experiments with pseudomonas and cholera bacteria; the test molecules seem to protect worms exposed to the virulent microbes. Bassler even tried her hand at drug development

Bacteria coordinate their behavior, and disrupting their communications might prevent or cure infections. (Above: Julia van Kessel examines bacteria in Bassler's lab. Opposite clockwise from upper left: *Vibrio harveyi* bacteria fluoresce when they sense a crowd; cholera bacteria exchange DNA; *V. harveyi* can be made to spell; pseudomonas bacteria often infect cystic fibrosis patients.)

ZACHARY DONNELL / BASSLER LAB; P. 79 ZACHARY DONNELL / BASSLER LAB; DR. KARI LOUNATMAA / PHOTO RESEARCHERS, INC.; SCIENCE SOURCE / PHOTO RESEARCHERS, INC.; ZACHARY DONNELL / BASSLER LAB; PP. 76-77 RICHARD SCHULMAN; ICON ILLUSTRATIONS: STEVEN NOBLE





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with a start-up company a few years ago. The effort foundered, and she is the first to concede that a medication based on the approach is probably a decade or more away. Nevertheless, the possibility of her work someday being translated from the lab bench to the bedside is part of her ongoing inspiration.

"We're scientists, we're curious about how nature works, but we're also do-gooders," she says. "It's fantastic to think that the same experiments we'd do to understand how information gets into cells could have a practical side to them, too."

IT'S A SUNNY SATURDAY IN PHILADELPHIA, and outdoors, in a park, is where most people might choose to be. Yet the lecture hall at the Wagner Free Institute of Science, with its dim amber lighting, wooden chairs, dried blowfish, human skulls and other Victorian bric-a-brac, is full of people mesmerized by the woman up front, who seems to be carrying her own piece of sun. Bassler's communication skills are not confined to divining petri dish dishings. She is a dynamo of a public speaker, who regularly dazzles both professional and lay audiences like this one with her vivid descriptions of microbial politics. "She can be very charismatic, but with just enough geekiness to let you know she's a serious scientist," says Stephen Winans of Cornell University. People love her dry humor and her blend of merry diva grandeur and aw-shucks insistence that she is just an "imposter" who does "genetics for dopes."

"Bacteria are the oldest organisms on earth," Bassler booms from the stage. "They've been here for four billion years. They make up 50 percent of the biomass of the earth and nearly 100 percent of its biodiversity."

If you think bacteria, you probably think disease, putrefaction and germs, and reach for your hand sanitizer. Bassler wants to set you straight. "You live in intimate association with bacteria, and you couldn't survive without them," she says. Trillions of human cells make up the human body, but there are at least ten times that number of bacterial cells in you or on you. You are, at best, only 10 percent human. Bacteria coat your skin in an ultrathin protective armor, which helps keep harmful microbes at bay. The bacteria in your gut make vitamins K and B12. You like lettuce? Your intestinal flora gamely generate enzymes so you can digest it. It's a happy trans-taxa tit-for-tat affair. For bacteria, "it's the good life, it's fat city" to dwell in the rich environs of a human being, Bassler says. It's much better, she goes on, than striking out on their own "in a puddle or free-living in the ocean. Those are nutrient deserts compared to us." Bacteria may be microscopic—three million can fit onto a pinhead—but they are not invisible. The next time you visit the Grand Canyon and your heart soars at the splendid strawberry-rhubarb striations of rock, take a moment to thank the makers. "Bacteria mineralized the rocks, they deposited the iron," Bassler says. "They made the geology we see."

Bassler's lab members (above left: Shu-Wen Teng with a fluorescence microscope and, right, spreading bacteria on a petri dish) can tell when their experiments succeed, because the bacteria start glowing. "If you can turn out the lights," says Bassler, "you're good."

Bassler lives not far from the Princeton campus with her husband, Todd Reichart, and their cat, Spark. Reichart, 48, is an actor and Web page designer. Their 1915 house is compact and elegant and the rooms are all painted different bright colors. "We're not afraid of color," Bassler says, "and color is something we agree on." The two have what a friend describes as a "playfully sparring" relationship. She complains he's a slob. He complains she doesn't listen. "Are you still here?" she says, glaring at him. "Don't you have somewhere to be?" Sorry, Bonnie, he says. "I'm a festering fact of your life." But when he does finally leave for the evening, she says, "We really do enjoy being together and doing things together. Todd is my biggest fan." They tried to have

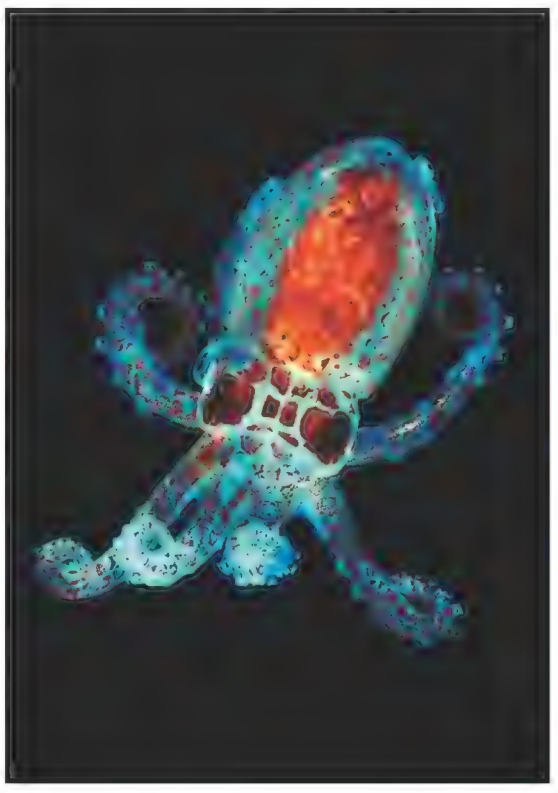
ZACHARY DONNELL / BASSLER LAB (2)

children, but it didn't happen. "It's not like there's a void," she says. "I'm a happy person. He's a happy man. We have an amazingly rich life, and I have all these kids in my lab."

Bassler grew up in Miami and later in Danville, California, with her businessman father, stay-at-home mother, older sister, Elissa, and younger brother, Rod. She had Barbie dolls; she was also a jock. "I was a huge athlete as a kid," she said. "I was on every sports team." She was a good student as well, and when she slacked off, her mother nudged her back in line. "She would tell me that when she was in college, a woman could only be one of two things, a teacher or a nurse," says Bassler. "But you, she'd say, you can be anything you want." Seeing that Bonnie loved animals, her mother found her a volunteer position at a zoo in Miami. "I got to be in there with the camels, operate on a lion," said Bassler. "It was the coolest job in the world." Later her mother helped her secure a position at a Kaiser Aluminum facility near Danville, testing bauxite samples from mines. "That's how I put myself through college," says Bassler. "I found that I loved working in a lab." She attended the University of California at Davis and decided to major in biochemistry.

Bassler was just 21 years old when her mother was diagnosed with metastatic colon cancer. Three months later, at the age of 46, she died. The loss is a void that Bassler can't seem to seal. "I'm older now than she was," says Bassler, her eyes rimmed with tears. "God, what a rip-off."

"I wish I could tell her that all the yelling at me to study and setting the timer when I was practicing piano was worth it," she says. "I wish I could tell her how great this life is."



The bobtail squid hosts glowing bacteria that provide camouflage in moonlight.

BASSLER ASSIGNS A TIME AND PLACE to the beginning of the great part of her life: the day of a lecture in graduate school when she first learned about the bobtail squid and its amazing bacteria-colored dream cloak. The squid lives off the coast of Hawaii and spends its days safely buried in the sand, emerging at night to hunt. It hovers near the surface of the water and waits for food, such as brine shrimp, to pass by. To avoid casting a shadow that would blow its cover, the squid uses a little trick. Under its protective outer sheath, or mantle, are lobes bulging with bioluminescent bacteria, billions and billions of *Vibrio fischeri* chemically glowing a cool cobalt blue. The squid can sense how much moonlight is hitting it, and it adjusts apertures on its glowing lobes accordingly. With light from above and below balanced, the squid can hunt shadow-free. The squid gets camouflage, the bacteria get shelter and nutrients, and scientists like Bassler get a magnificent system to ply, one where the "aha!" light bulb is more than a metaphor.

Through studying *V. fischeri*, researchers learned about bacterial sociability. They found that the bacteria would luminesce only when they were in a crowd, packed together, and would desist from glowing should they float away from their fellows in the lonely dilution of the sea. The researchers isolated the molecule that allowed the bacteria to keep track of one another; they called it an autoinducer.

After earning her doctorate in biochemistry at Johns Hopkins University, Bassler worked as a postdoctoral fellow at the Agouron Institute, a research foundation in La Jolla. While there she fell hard for blinking squid and other lanterns of the sea. She studied *V. fischeri* and moved on to a related species called *Vibrio harveyi*. She liked the ease of manipulating bacteria, how she could make mutants, push genes around, cross and backcross strains. She especially liked that her weird luminous workhorses would glow if she did the right thing but not if the experiment flopped, a visible indicator that her research team still takes advantage of today. "If you can turn off the light switch in my lab," Bassler says, "you're good."

It was while studying *V. harveyi* that Bassler helped make a couple of key discoveries: first, that *V. harveyi* had its own, chemically distinct version of an autoinducer, a members-only signal for keeping track of local *V. harveyi* numbers; second, that both *V. harveyi* and *V. fischeri* secreted and responded to another sort of molecule. This molecule was able to get a rise out of *V. harveyi* and *V. fischeri* alike, regardless of its source. Bassler had stumbled on her bacterial Esperanto. She dubbed the molecule autoinducer 2, and pretty soon she was finding it in virtually every bacteria species she tested: in shigella, salmonella, E. coli and *Yersinia pestis*, the bearer of plague.

Bassler and her colleagues have examined the molecule in atomic detail and seen what it looks like when it is clasped by its appropriate sensory protein—the "ear" that allows bacterial cells to hear the molecule's cry. They have begun charting precisely how different species of bacteria respond to the universal signal when it is delivered either alone or in combination with other quorum-sensing molecules. They have shown, for example, that when cholera bacteria receive a mix of the private cholera-only signals and the shared we're-all-bacteria-in-this-together signal, the cholera microbes become extremely virulent. They have found that the common-language molecules are micromanaged by cellular busybodies called small RNAs. They have found that the sys-

NATALIE ANGIER *is a Pulitzer Prize-winning science writer and the author of* The Canon, Natural Obsessions *and other books.*

GARY BELL / OCEANWIDEIMAGES.COM

"You are, at best, only 10 percent human," says Bassler (at home with cat Spark). Our cells are outnumbered by bacteria.

tem is . . . complicated. "It's fun, but it's hard," says Bassler. "And that's good, because I need the job."

MOST INTERESTING PEOPLE have their share of contradictions, but Bonnie Bassler is like a Greek diner menu of contradictions: every time you think you've reached the end, you unstick another page of options. She is proud. She is humble. She is impatient. She's a saint. She has a coffee cup that says "Diva," but she freely shares her insecurities. "I'm so worried that my star is falling, that I'll run out of juice." She jokes about being bored and wanting to go home, but to anyone who works with her she is a perpetual anti-boredom machine.

"Her enthusiasm is very contagious, and it's always contagious," says graduate student Carey Nadell. "After the first few conversations we had, when she'd get me excited about the science, I thought the effect would wear off, the way it does with most things. But that hasn't happened. I always become happier about doing the science after talking with her." That cheerleader spirit is not limited to science. Monday through Friday, Bassler is up by 5:40 a.m. and goes to the local YMCA, where she teaches aerobics for an hour. "It's a very challenging class," says Jean Schwarzbauer, a Princeton molecular biologist who is one of Bassler's closest friends and a fellow gym rat. "People come thinking aerobics is something to work up to, but she gives you a day to get used to it and then she starts yelling—in a friendly way—if you're not working hard enough." Customers come back for more. "You see a lot of the same people over and over," says Schwarzbauer. "She calls it a cult."

Some of her scientific peers have complained that Bassler sometimes hogs the spotlight. "I think she's a very talented scientist and I've promoted her career," says Peter Greenberg, who studies quorum sensing at the University of Washington. He added, however, that Bassler can have "a tough time" giving others credit. Bassler admits that she's a "ham" and that she's glad her last name begins with B so that she's at the top of her department's Web page. Yet she is also a zealous collaborator, forever seeking new people to work with: chemists, physicists, X-ray crystallographers, structural biologists, mathematicians, evolutionary theorists. She met a condensed-matter physicist while standing around the baggage claim at a Mexican airport, and the next thing you knew she was collaborating with him. A student in Bassler's lab named Julie Semmelhack happened to mention to her father, Marty Semmelhack, that she'd been working on an interesting molecule in the lab. The father, a chemist, instantly recognized the structural profile of the molecule—"It's a furanone!"—so of course Bassler had to work with him, too.

"Working with Bonnie has convinced me that under the right circumstances and with the right people, collaboration can be more rewarding than working for yourself," says Frederick Hughson, a molecular biologist at Princeton who studies the structure of proteins and other molecules.

Scientists of Bassler's caliber often have 50 or 60 people working for them, all vying for attention and hot projects. Bassler has 15 or 16 people in her lab, and she prides herself on picking her protégés well. "Only two people haven't worked out in all these years," she says. Her requirements are simple. If you want to work in her lab, if you want to be part of the Bonnie Bassler "brand," as she puts it, you must be extremely ambitious, self-motivated, smart, tenacious, handy with a pipette and not a jerk. "My group selects for a certain kind of person, and that person tends to be really, really nice," she says. "After all, they're the ones who will be working with them elbow to elbow for five years, and they notice these things." A candidate visits the lab, and members tell Bassler what they think. "It's quorum sensing," she says.

Members of her lab are clearly wedded to Bassler. Some have even been wedded by her. Last year, when Yunzhou Wei was planning his nuptials, he heard from another scientist at Princeton that Bassler was licensed to perform wedding ceremonies.

"I sent a dollar to a church on the Web, and I got the certificate," Bassler says. "I'm sure it's a complete tax scam." She'd already officiated at two weddings and a baptism when Wei asked her to do the honors. "I'm a sucker," Bassler sighs.

"We had 60 people come from all around the country," says Wei. "Bonnie made a really good ceremony. It brought us all very close together."

With people, as with bacteria, nothing is stronger than community, united in purpose by just the right words.

RICHARD SCHULMAN

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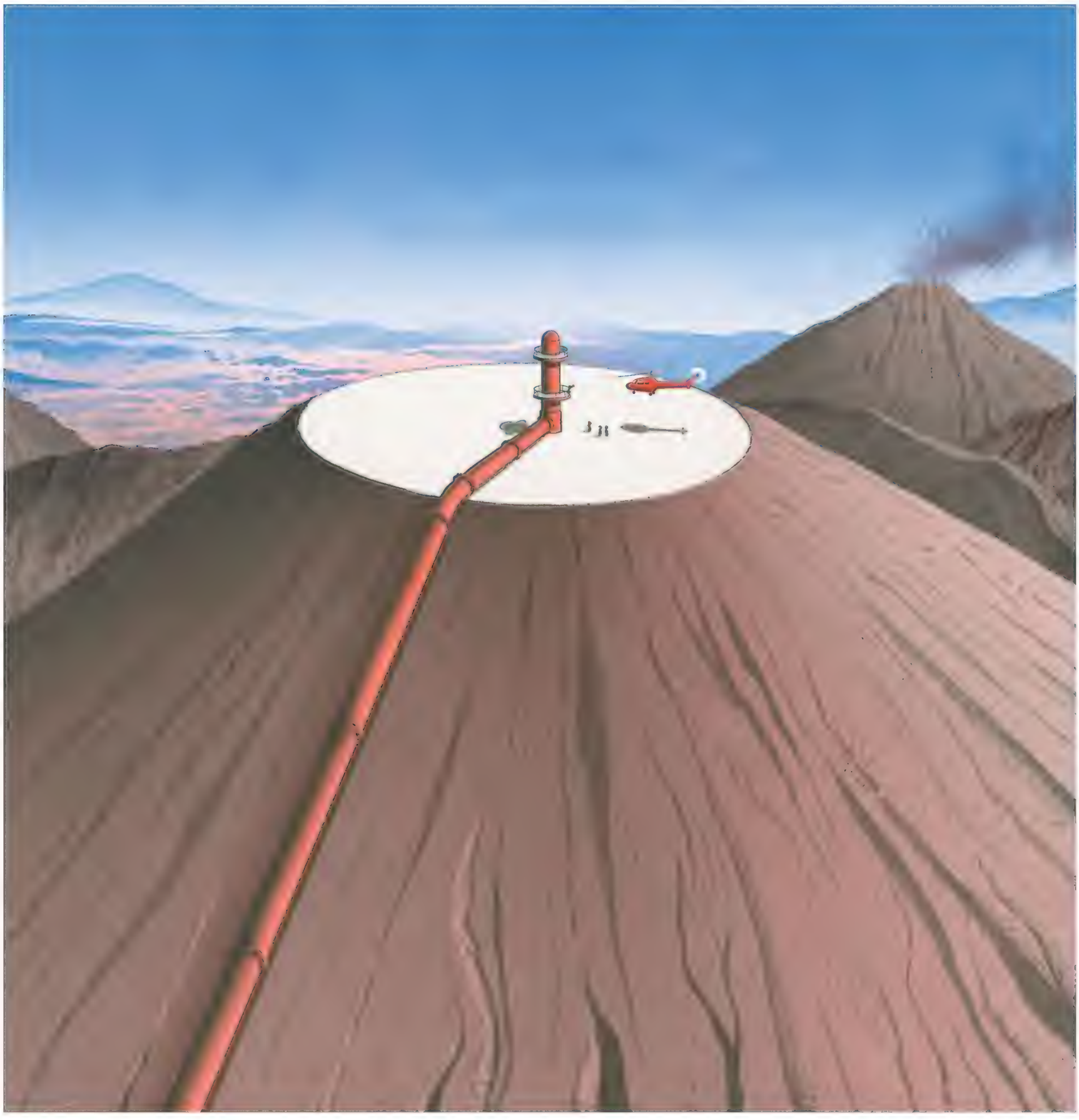
PEAK ENERGY

Asked to imagine life in 2050, the artist **Guy Billout**, author of the mind-bending book *Something's Not Quite Right*, wonders why the quest for alternative energy has overlooked the volcano



MEDICINE & SCIENCE

40 THINGS TO KNOW

Q&A

MELINDA FRENCH GATES SAVING LIVES

CHILD FRIENDLY
Gates (with caregivers in Rampur Bhuligadha, India) says infant deaths can be halved by 2025.

"WE DECIDED WE WOULD USE OUR MONEY *to help give everyone, no matter where they live, the opportunity to live a healthy and productive life," Melinda French Gates tells* SMITHSONIAN.

One of the few people in the world who can say such a thing and mean it literally, Gates is a co-chair of and, by most accounts, the conscience of the Bill & Melinda Gates Foundation, the world's largest philanthropy.

It was in 1994 that Melinda French, then a Microsoft executive, married the company's founder and chairman, Bill Gates. The couple launched the foundation that same year with a donation of stock worth $94 million, and has since made contributions valued at $28 billion.

The foundation has given some $22.7 billion to development, education and health projects in the United States and more than 100 nations. Executive editor Terence Monmaney's e-mail exchange with Melinda Gates focused on the charity's health efforts.

BARBARA KINNEY / BILL & MELINDA GATES FOUNDATION

Your foundation has donated $1.5 billion to the GAVI Alliance, a partnership to deliver vaccines to children in developing nations. The program may have averted as many as five million premature deaths. What does its success mean?

It reinforces our conviction that strategic investments can make a huge difference in poor people's lives. GAVI also teaches us that partnerships are critical to having an impact at the scale we're aiming for. If these partnerships keep growing, we believe vaccines can significantly reduce child mortality rates in the near future. That's why vaccines are the foundation's number one priority. We've already spent $4.5 billion to help develop and deliver vaccines, and in January we announced a $10 billion commitment to extend this work over the next decade.

As you look toward 2050, what achievements in global health do you anticipate?

I believe polio and malaria will be eradicated. I hope an AIDS vaccine will be widely available. Not only will those three changes alone save about three million lives per year compared to today; they will also save billions of dollars we're currently spending on treatment, which means we can invest more in other priority areas.

One of those areas is neonatal and maternal health. I expect that by 2050, women around the world will have the ability to give birth in a safe, healthy environment and have access to basic health care for themselves and their families. Right now, almost nine million children under the age of 5 die every year, four million of which are newborns. I am confident we'll see a dramatic decline in both of these numbers. In fact, we believe that the total number of deaths among children younger than 5 can be cut in half by 2025, using tools that are already available.

Poverty is often viewed as intractable. What has your experience taught you about it?

History has shown that it's possible for people to overcome even extreme poverty and hunger. Many countries that used to receive aid in the 1960s, like Brazil and Thailand, are now net donors. In fact, the number of countries receiving aid has been cut in half since the 1960s.

We also know that certain strategies have an immense impact. Investing in agriculture, for example. Advances in agriculture during

the Green Revolution doubled food production, saved hundreds of millions of lives and laid the groundwork for broader development in many countries.

Recent history has also shown that access to financial services can empower people, especially women, and build up families and entire communities. At the Gates Foundation, we are particularly interested in the potential of small-scale savings accounts to improve poor people's lives. When people have reliable access to savings, they don't risk total destitution if there's a death in the family or a bad crop.

In January, I visited some villages being served by Opportunity International Bank of Malawi to see how savings impact people on the ground. It's building inexpensive bank branches—one was made out of three shipping containers—and setting up kiosks in shopping centers and post offices. It also operates seven trucks that bring banks to remote places, which is important since 85 percent of Malawians live in rural areas. I saw people waiting in an hour-long line to make an average deposit of about 200 Kwacha, or $1.40. That's how much demand there is for savings in poor communities!

The Gates charity pledges $10 billion for vaccines (a foundation-supported PATH clinic in Nairobi).

Are there foreign aid approaches that are not as effective as you once thought they would be?

Certainly there has been spending that hasn't had its intended impact, and we've learned a lot from those experiences. But on the whole, the things that Bill and I have seen and heard on our travels—as well as the key statistical indicators—make it clear that U.S. investments in global health are working. Dollar for dollar, global health is the U.S. government's best investment.

But too many Americans have no idea about the extraordinary value of these programs. Nearly half of Americans think that foreign aid is one of the biggest parts of the federal budget, even though it actually accounts for less than 1 percent of government spending. And global health funding accounts for just a quarter of all foreign aid—about one-quarter of 1 percent of the overall federal budget.

What will make a lasting impact on poverty?

I'm excited about the ways technology is helping poor people make progress faster. In Kenya, nearly nine million people are using mobile phones to transfer money. That means that if a person needs to send money to her mother in a faraway village, it's now as easy as sending a text message. As regulators find ways to ensure the safety and security of new financial services and more new products are designed to meet the needs of the poor, financial security will be within reach for millions of families in the developing world. They will have the ability to save for emergencies, pay for health care for their families, start a business or send their children to school.

What importance does the Gates Foundation put on curbing population growth?

We often get asked if improving health or lowering child mortality rates will contribute to overpopulation. Bill and I used to ask ourselves the same question. We learned that just the opposite is true. When a country's health improves, it sees tremendous benefits in all sorts of areas, including lower birthrates. Research shows that when women know their children will survive to adulthood, they choose to have fewer children.

Inevitably, the foundation has been criticized as too powerful and insufficiently transparent. What do you make of such criticisms?

It's essential that critics challenge our thinking and question our strategies. That's how we get better at what we do. We have always been adamant that our success depends on our partners in the field, and we make a point of getting their feedback. We recently conducted an exhaustive survey of all our grantees to understand how we can work more effectively with them. We also have advisory boards that provide regular, expert counsel to our three program areas. In terms of transparency, we publish updates about our strategies and what we are learning at www.gatesfoundation.org.

NO. 20

HEALTH WORKERS WILL ERADICATE ONE OF HUMANITY'S WORST SCOURGES: MALARIA.

You have referred to mistakes as "learning opportunities." Which have had the greatest impact on your thinking?

One thing that was driven home on my last trip to India was how important it is to pair the best science with a deep understanding of traditional cultures. I was in Rae Bareli, a rural village in

WENDY STONE / CORBIS

northern India, to see a project called Shivgarh. This is a Johns Hopkins research site that our foundation and USAID funded together, and the goal is to decrease infant mortality. The first six months of the Shivgarh project was spent on research to understand current newborn care practices, with a focus on identifying the practices that lead to neonatal deaths, and analyzing the perceptions on which these practices are based.

The researchers found that most mothers didn't understand the importance of skin-to-skin contact, immediate breast-feeding or keeping the umbilical cord clean. However, by making analogies to important local customs, health workers were able not just to tell women what to do but also to explain why they should do it. In less than two years, Shivgarh has seen a 54 percent reduction in neonatal deaths in the target areas.

Studies suggest development aid goes furthest if it is directed to women. Is that your experience?

The health of women is inextricably linked to the health of young children, families and entire communities. We invest in programs like Save the Children's "Saving Newborn Lives" initiative, which helps pregnant women and their babies with simple strategies like increased access to skilled birth attendants and education about hygiene and breast-feeding. We also support programs to increase access to family planning and HIV prevention services in developing countries.

But agriculture may be the area where the special role of women in development is most clear. Most small farmers in sub-Saharan Africa and South Asia are women, but a lot of agricultural interventions don't take that into account. Some programs aim to increase the productivity of crops without understanding that higher production can mean that women have to work longer and harder in the field, leaving them less time to care for their households; that can undermine the welfare of the household in general. And we know that when a woman gets cash for her work, she is more likely than her husband to spend it on things like food and school fees.

In your travels, what experience has moved you most?

I was in Malawi earlier this year, and at a hospital in Dowa, I saw two newborn babies lying in an incubator, side by side. The first baby, who had just been born at the hospital, wasn't breathing because of birth asphyxia. The baby turned purple, and I watched as the doctors worked to clear the lungs. They administered oxygen and were able to get the baby breathing again. The second baby was also born with birth asphyxia. Only that baby wasn't born in the hospital; it was born a few hours before and brought to the clinic. For that baby, it was too late. That tragedy made it very clear what's at stake with the newborn health work we're investing in. The work our partners are doing to help mothers deliver their babies in a healthy environment saves lives.

It's heartbreaking and inspiring to be in these rural villages and see what the mothers and fathers are up against—and how much they overcome. When I see that a baby in Malawi can be saved because she's born in a hospital, I am filled with hope that a similar approach will work for mothers and babies in other countries. To know that real change is possible is what gives me optimism.

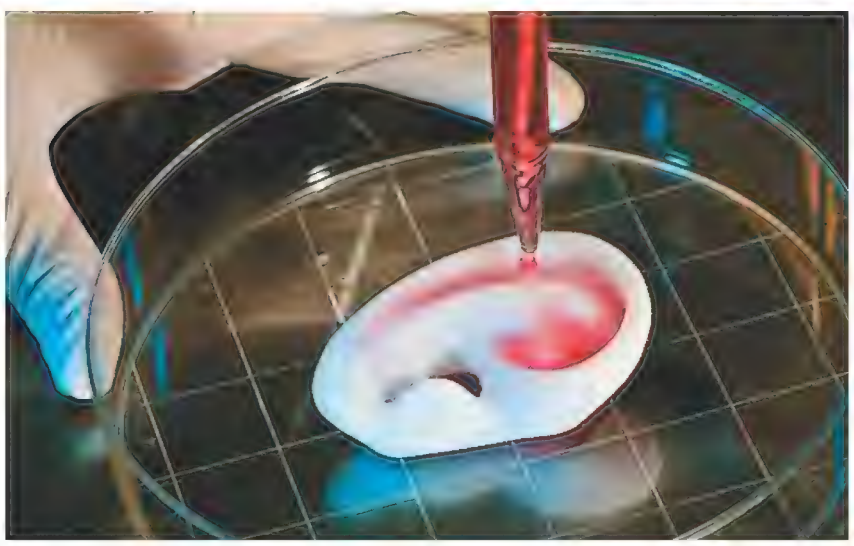
ORGANS MADE TO ORDER

It won't be long before surgeons routinely install replacement body parts created in the laboratory BY GRETCHEN VOGEL

ANTHONY ATALA WORKS IN THE BODY SHOP OF the future. He is the director of the Wake Forest Institute for Regenerative Medicine in Winston-Salem, North Carolina, and he and his colleagues use human cells to grow muscles, blood vessels, skin and even a complete urinary bladder. Much of the work is experimental and hasn't yet been tested in human patients, but Atala has implanted laboratory-grown bladders into more than two dozen children and young adults born with defective bladders that don't empty properly, a condition that can cause kidney damage. The bladders were the first lab-generated human organs implanted in people. If they continue to perform well in clinical tests, the treatment may become standard not only for birth defects of the bladder but also for bladder cancer and other conditions.

NO. 21
MEDICAL RESEARCHERS COULD ENABLE A PERSON TO REGROW A SEVERED LIMB.

Atala and co-workers make replacement parts out of patients' own raw materials. To produce a bladder, they remove a small piece of a patient's organ and separate out muscle cells and urothelial cells, which line the urinary tract. They put the cells into lab dishes and bathe each type in a fluid that prompts them to multiply. After six weeks, there are enough living cells for an entire bladder. The researchers then pour the muscle cells onto the outside of a scaffold made of collagen, the protein in connective tissue, and polyglycolic acid, a material used in absorbable sutures. Two days later, they coat the inside of the scaffold with urothelial cells. The new bladder is nurtured in an incubator that mimics body



Using scaffolds and a patient's own cells grown in a laboratory, researchers are building replacement body parts. Clockwise from top left: Anthony Atala at Wake Forest; a heart valve; a bladder similar to those being tested in humans; an ear.

conditions, allowing the cells to grow and knit together. The bladder is then implanted into a patient, where the scaffold gradually dissolves. The researchers have standardized the bladder-growing procedure, Atala says with a smile, and now make "small, medium, large and extra-large sizes."

Regenerative medicine's once-wild ideas are fast becoming reality. Late last year, Organovo, a biotech company in San Diego, began distributing the first commercially available body-part printer. Yes, you read correctly: a *printer* for body parts. Using the same idea as an ink-jet printer, it jets laser-guided droplets of cells and scaffold material onto a movable platform. With each pass of the printer head, the platform sinks, and the deposited material gradually builds up a 3-D piece of tissue. Regenerative medicine laboratories around the world have relied on the printer to generate pieces of skin, muscle and blood vessels. Atala's lab has used the technology to construct a two-chambered mouse-size heart in about 40 minutes.

Atala and his colleagues have also managed to fashion lab-built kidneys that produce urine when implanted into experimental animals. And within a few years, he says, human skin could be coaxed into growing in a lab and be given to burn victims and other patients who today must undergo painful skin grafts.

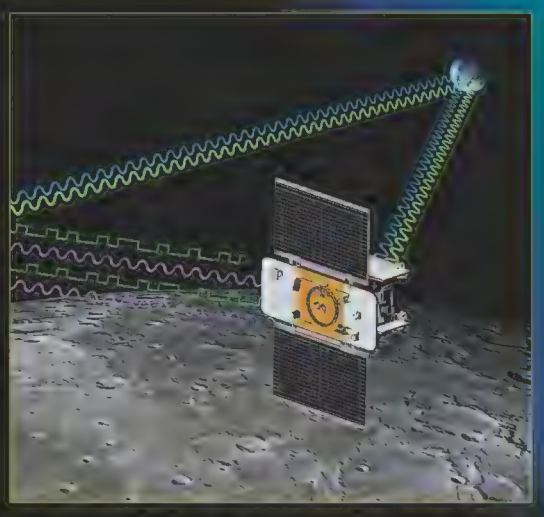
Organs grown outside the body will transform medicine, Atala predicts, but spurring repair and regrowth within the body will be just as important. He and other scientists foresee injecting healthy cells and growth-inducing molecules into diseased or injured lungs, livers and hearts, prompting them to regenerate. Then there's the ultimate challenge: Could a patient someday regrow an entire limb?

"It is not outside the realm of possibility," Atala says. "If a salamander can do it, why can't a human?" Scientists are getting closer to understanding the subtle genetic and physiological processes that allow salamanders to regenerate their limbs from scratch. More clues are coming from lab mice that have a genetic mutation that allows them to partially regrow severed digits.

Will doctors 40 years from now be able to help humans regrow severed spinal cords, damaged hearts or even lost limbs? Atala says he is optimistic: "The things that are possible today were a dream 20 years ago."

GRETCHEN VOGEL *lives in Berlin and writes for* Science.

WAKE FOREST UNIVERSITY BAPTIST MEDICAL CENTER (4)



ESA; JPL / NASA; ESA; JPL / NASA; PP. 88-89 SPACE SCIENCE INSTITUTE / JPL / NASA

From top: If all goes as planned, the BepiColombo spacecraft will search for ice on Mercury; the Mars Science Laboratory will drill for rocks; the ExoMars Trace Gas Orbiter will seek methane in the Martian atmosphere, a possible sign of life; the GRAIL mission will map the Moon's interior.

NEXT IN SPACE

Probes and landers sent into the final frontier will bring us closer to

"I AM CONVINCED WE WILL FIND PAST OR PRESENT LIFE IN THE solar system or on a planet surrounding another star in the next 40 years," says Edward Weiler, an astrophysicist and associate administrator of the Science Mission Directorate at NASA headquarters in Washington, D.C.

Weiler's prediction is based partly on recent discoveries of creatures living in extreme environments previously considered uninhabitable, such as 600 feet beneath the ice in Antarctica, where a shrimp-like critter has been found. "As long as we have water, energy and organic material," Weiler says, "the potential for life is everywhere." He hopes the imminent discovery of extraterrestrial life will finally put to rest the idea that Earth is unique: "It is the last crumb on the plate of human arrogance."

Though sending humans into space might stir the greatest public attention, there are no solid plans for doing so in the near or even distant future. But space-based science will boom. Here's a celestial mystery tour of future probes and observatories due to be launched by NASA, the European Space Agency (ESA) and the Japanese Aerospace Exploration Agency (JAXA):

INNER PLANETS

NASA's MErcury Surface, Space ENvironment, GEochemistry and Ranging (MESSENGER) probe, launched in 2004, will become the first spacecraft to orbit the planet closest to the Sun on March 18, 2011. Three years later, a joint ESA-JAXA mission will send the BepiColombo spacecraft to Mercury, where it will map the planet and investigate its magnetosphere. Scientists hope to learn whether ice exists in permanently shadowed craters near the poles.

NASA's robotic Mars Science Laboratory (launch: 2011) is a rover that will analyze soil and rock samples, looking for organic materials. One key question is whether Mars ever was—or is currently—capable of supporting microbial life. Later in the decade, the joint NASA-ESA ExoMars Trace Gas Orbiter (launch: 2016) will study the Martian atmosphere, paying special attention to methane gas, first detected in 2003. Because one source of methane is biological activity, it's conceivable that life might currently exist on Mars.

Closer to home, NASA's Gravity Recovery and Interior Laboratory (GRAIL) mission (launch date: 2011) will send twin spacecraft in tandem orbits around the Moon; the satellites will work together to make highly sensitive gravitational field measurements. This data will allow scientists to map the lunar interior, from crust to core.

answering cosmic mysteries BY MARK STRAUSS

NO. 22
SCIENTISTS WILL FIND PROOF OF OTHER LIFE, IN OUR SOLAR SYSTEM OR BEYOND.

OUTER PLANETS

A joint NASA-ESA Europa Jupiter System Mission (possible launch: 2020) will send two robotic orbiters to conduct a three-year study of Jupiter and its moons: Europa (beneath its icy surface an ocean might contain enough oxygen to support life), Ganymede (it's the only moon that has an internally generated magnetic field), Io (the solar system's most volcanically active body) and Callisto (its heavily cratered icy crust might hide an ocean deep in its interior).

NASA is studying a mission, for launch in the 2020s, that would visit the only moon known to have an extensive atmosphere—Titan, a satellite of Saturn. The concept consists of a balloon that would hover in Titan's nitrogen-rich clouds, a lander that would splash down in one of its methane seas and an orbiter that would relay data, in addition to making atmospheric measurements.

Meanwhile, the earlier NASA-ESA Cassini-Huygens mission—launched in 1997 to explore Saturn and its moons—might be extended to 2017, enabling scientists to collect data on weather changes as the ringed planet enters its summer solstice.

Launched in 2004, ESA's Rosetta probe will rendezvous with comet 67/P Churyumov-Gerasimenko in 2014. A lander will study the surface, and an orbiter will follow the comet another two years.

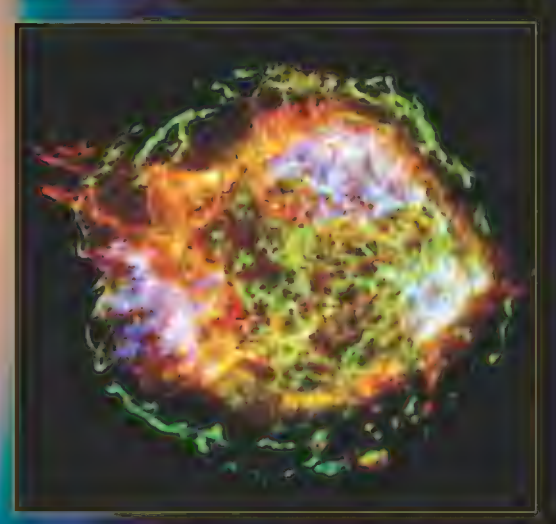
THE COSMOS

NASA's NuSTAR (launch date: 2012) will rely on high-energy X-rays to study the cosmos. Among its missions will be gazing at supernovas, or exploded stars, for clues explaining how and why they self-destruct.

Designed to penetrate dust clouds, NASA's CALISTO orbiting observatory (launch: 2015) will search interstellar space for traces of organic molecules, the building blocks of life.

The James Webb Space Telescope (launch: 2014) will collect infrared radiation with a mirror 21 feet in diameter. The goal is to study signals generated when stars and galaxies formed in the aftermath of the Big Bang 12 billion to 14 billion years ago. NASA's Weiler says the telescope "will have the ability to look back at the birth of matter itself."

MARK STRAUSS *is a senior editor.*



MICHAEL CARROLL / NASA / ESA; ESA; U. HWANG, ET. AL. / GSFC / CXC / NASA; JPL / NASA

From top: The Europa Jupiter System Mission will survey the massive planet and its moons; the Rosetta probe will land on a comet's surface; the NuSTAR observatory will gaze at exploded stars (Cassiopeia A is shown); the CALISTO telescope will search interstellar space for traces of organic molecules.

MASTERS OF DISASTER

Asteroid hunters are determined to protect human beings from outer space invaders **BY ROBERT IRION**

MOST OF US DO WHAT WE CAN FOR THE ENVIRONMENT, but Rik Hill's actual job is to protect the planet. "Whoa, look at that!" he says, pointing at a moving blip of light on a computer screen. "It's an unknown object. We just discovered one."

We're in an observatory on the summit of Mount Lemmon, a 9,000-foot peak north of Tucson, Arizona.

Hill's boss, Ed Beshore, leans in and nods. "That's an N-E-O," he says, referring to a near Earth object. "It's a nice one. It's bright, and it's moving fast."

Hill, an astronomer, sends an e-mail to the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, where the Minor Planet Center monitors hundreds of thousands of small bodies in our solar system. The message gives the object's coordinates at the time of its discovery so other astronomers can track it. And they'll want to: an NEO is any asteroid or comet that will come within about 30 million miles of Earth's orbit.

We'll find out in the morning whether this NEO poses a threat. For now, Hill leans back, a cup of strong coffee in hand, and grins. "It's not even midnight, and it's a good night already," he says. By dawn, he will spot two more.

I went to Mount Lemmon to see the top NEO hunters in action. Beshore and Hill are part of the Catalina Sky Survey, which has found about 2,500 NEOs in the past decade—including 577 in 2009, some 70 percent of the total discovered that year. The rocks range from the size of tables to mountains. Most will bypass Earth. But NEOs have plowed into our planet countless times before, and will do so again.

In October 2008, the survey's Rich Kowalski observed a small NEO from this telescope. Within two hours, the Minor Planet Center used sightings by others to chart its trajectory. The asteroid would hit Earth in less than a day. Observers worldwide locked onto it, capturing 570 telescope images. NASA scientists calculated it would strike the Nubian Desert of northern Sudan. It was only the size of a small pickup truck, and most of it would burn up in the atmosphere. Even so, news of the imminent impact went all the way to the White House.

About 19 hours after Kowalski discovered it, asteroid 2008 TC3 lit up the sky above Sudan with the energy of more than 1,000 tons of TNT. Black fragments as large as apples landed in the desert. Two months later, NASA-led researchers collected hundreds of the extraterrestrial rocks.

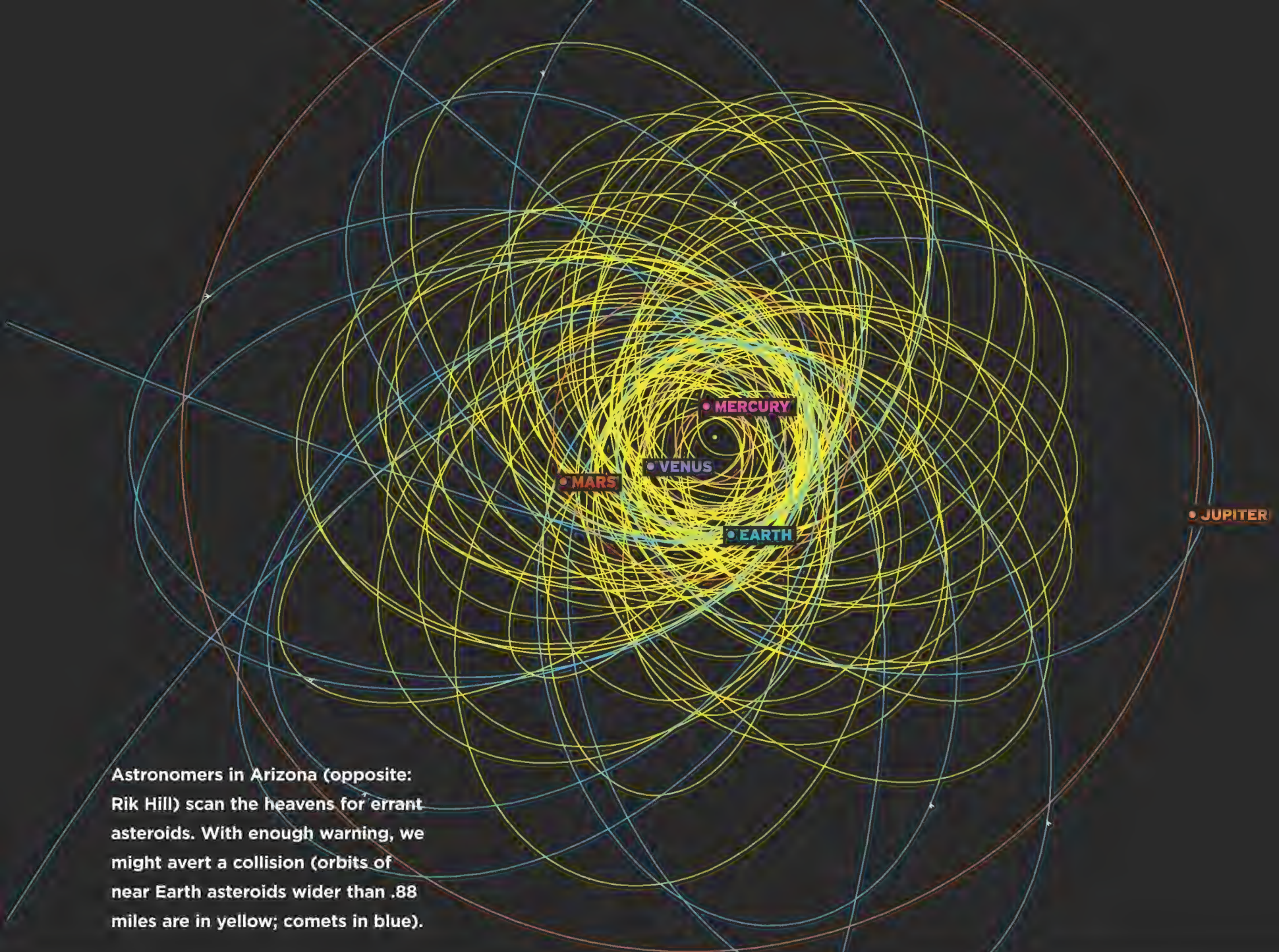
In one sense, spotting the incoming asteroid was a triumph, because it demonstrated that astronomers can detect even a small projectile heading our way. But the feat was also sobering, because they saw it too late to do anything about it. Hill and his fellow NEO hunters hope to detect large asteroids sooner, preferably years or decades in advance.

"It's the only natural disaster we can stave off," says Don Yeomans, manager of NASA's NEO command center at the Jet Propulsion Laboratory (JPL) in Pasadena, California.

ODDBALLS OF THE solar system, asteroids are battered chunks of rock and metal that have tumbled around the heavens since the Sun's eight major planets (plus demoted Pluto) formed about 4.6 billion years ago. Astronomers have cataloged about a half-million asteroids, most in the gap between the orbits of Mars and Jupiter. About 7,000 known NEOs loop wildly among the inner planets, following paths that shift in response to gravity and the Sun's heat. "Their orbits are all over the place," says Paul Chodas of JPL. "They're rebels."

In the desert 175 miles north of Tucson, Meteor Crater is the scar where a boxcar-size hunk of iron slammed into Earth 50,000 years ago. The crater is nearly a mile wide and 550 feet deep, edged with layers of warped and shattered rock. The asteroid blew up with the energy of the largest hydrogen bombs ever detonated on Earth, vaporizing the desert and unleash-

JASON MILLSTEIN / ILLUME / AURORA SELECT



Astronomers in Arizona (opposite: Rik Hill) scan the heavens for errant asteroids. With enough warning, we might avert a collision (orbits of near Earth asteroids wider than .88 miles are in yellow; comets in blue).

PAUL CHODAS / JPL / NASA

ing deadly supersonic winds for many miles. I visited the crater as night fell, and I felt keenly aware that fragments of the solar system can invade our cozy realm of Earth and Moon.

If a 100-foot-wide asteroid hit Earth, the shock wave from its explosion in the atmosphere could flatten trees and kill every large animal for hundreds of square miles. That's just what happened in 1908 at Tunguska, Siberia. The odds are roughly one in ten that such a blast will occur in the next 40 years. An asteroid 500 feet across could destroy a metropolitan area or spawn massive tsunamis. Those impacts occur every 30,000 years, on average.

Hundreds of known NEOs are more than a mile wide. If an asteroid that big struck Earth, firestorms could produce worldwide clouds of soot that would block sunlight and plunge the planet into an "asteroid winter." That happens every few million years, scientists estimate. Once every 100 million years or so, an even larger asteroid may cause a mass extinction; most scientists believe a six-mile-wide asteroid doomed the dinosaurs 65 million years ago.

Astronomers with the Catalina survey find new NEOs almost every night. They start by taking four pictures of the same patch of sky, with ten minutes between each exposure, and compare them on a computer screen. While background stars shine in the same place in each image, NEOs appear as four distinct dots along a straight line. The astronomers are skilled at ruling out man-made satellites, electronic sparks from cosmic rays and other streaking objects that could be mistaken for an NEO. "They look at everything with the human eye," NASA's Yeomans says. "They've been doing it for so long, and they're so dedicated."

NO. 23
ASTRONOMERS WILL TAKE ACTION SO WE DON'T SUFFER THE FATE OF THE DINOSAURS.

Hill, who has used telescopes since he was a child during the Sputnik era, has been on the team since 1999. He has found more comets—22—than all but three other people in history. (Comets usually originate in the outer solar system and are less common in Earth's neighborhood than asteroids.) During my visit to Mount Lemmon, he made a trumpeting noise just before he pointed out the first NEO to us. "I love what I do," he says. "I would do this for free."

The Catalina Sky Survey consists of nine astronomers using two modest telescopes in Arizona and one in Australia. The team refurbished a long-unused telescope at Mount Lemmon with a 60-inch mirror, small by modern standards. NASA provides $1 million per year—peanuts in astronomy circles.

ROBERT IRION *has written about comets, black holes, new planets and other astronomical phenomena for* SMITHSONIAN.

At Mount Lemmon (left), observers routinely detect asteroids as large as the one that created mile-wide Meteor Crater (right).

"We're very careful and meticulous," says Beshore, a former software engineer who directs the survey. "We get the numbers just right."

As it happens, astronomers at the Catalina telescope in Australia and other sites around the world took pictures of the NEO after Hill discovered it the night of my visit, allowing the Minor Planet Center to calculate its orbit. By the next morning, the results had been posted online: the asteroid didn't threaten Earth. I felt a bit let down; no worldwide scoop for me.

Before Beshore joined the survey in 2002, he was skeptical that he'd spot any hazardous asteroids. "Then I realized, my God, the sky is full of these things," he says. "I have more perspective that yes, this could happen, we might get hit. It would be really satisfying to find an object and then do something about it."

DON YEOMANS often thinks about what that might be. Scale models of asteroids fill the windowsill of his office at JPL in Pasadena. He runs the lab's NEO clearinghouse, which looks nothing like a Hollywood depiction of a planetary-defense headquarters. There are no wall-size display screens, no blinking panels or red telephones, just ordinary-looking offices. But the workers are well aware of their lofty mission. "We don't let our guard down, even for a day," Yeomans says. "It's our job to monitor the inner solar system and make sure none of these objects gets close to the Earth."

The tracking starts at the Minor Planet Center, which archives data from a global network of professional and amateur astronomers. "We inventory the solar system," says center director Tim Spahr. "If the world wants to know about an asteroid, we have the catalog."

The JPL team takes orbit data from the Minor Planet Center and refines it, asteroid by asteroid. A computer program called Sentry projects each NEO's orbit for 100 years. Once an asteroid starts approaching Earth, it will do so again and again in an orbital waltz driven by gravity as both bodies travel around the Sun. Most NEOs will plunge into the Sun after a million years of this pas de deux.

"It's a mathematical problem, and a fascinating one at that," says JPL's Chodas. "It's just exhilarating."

A 900-foot-wide asteroid called Apophis caused a stir in 2004 when JPL calculated there was a 3 percent chance it would slam into Earth in 2029. With the next set of images, JPL's Steve Chesley forecast a more precise orbit, and he ruled out an impact. However, there's still a tiny chance it will hit in 2036 or 2068—depending on the exact route the asteroid follows during its next pass near Earth.

If Apophis did drift onto a collision course and was headed for Russia, a Russian military official said last year, his country might prepare a mission to knock it off course. But that would be premature, Yeomans says. "You have to be careful about moving asteroids around in space," he adds, lest a deflection inadvertently steer Apophis toward Earth. "They should only be moved if they are a real threat."

Among the groups studying how best to prevent a collision is the B612 Foundation, named for the asteroid in Antoine de Saint-Exupéry's *The Little Prince*. Led by Apollo 9 astronaut Rusty Schweickart, the foundation has proposed a mission to a nonthreatening asteroid to test whether gravity from a hovering spacecraft could shift the asteroid's orbit. "You don't want to blow them up," says Schweickart. "All you need to do to protect Earth is to push them gently."

Exploding an asteroid would require deploying nuclear weapons in space, scientists say. They caution that no one knows how asteroid material would respond to such a blast. Some NEOs are thought to be loosely packed piles of rubble. One recent study suggests that a deliberate explosion would barely disperse the pieces, and they would reassemble under their own gravity.

In Yeomans' mind, scientists have already demonstrated the best technique: ramming. In 2005, a NASA science mission called Deep Impact crashed an 816-pound copper mass into a comet to learn more about its icy interior. If scientists were to detect a 600-foot-wide asteroid ten years in advance, Yeomans says, it could be deflected with a two-ton projectile traveling six miles per second. He says that's enough to make it miss the Earth. Barely.

But given the limited number of astronomers and the small telescopes scanning the sky for asteroid threats, says Yeomans, we probably won't see a small incoming object until it's just a week or two away from hitting us. "In that case," he says, "all you can do is evacuate."

JASON MILLSTEIN / ILLUME / AURORA SELECT; STEPHEN ALVAREZ / NATIONAL GEOGRAPHIC STOCK

MELVIN KONNER CATCHING UP WITH KIDS

THE ANTHROPOLOGIST AND PHYSICIAN *Melvin Konner began his career in the late 1960s studying how hunter-gatherer people in southern Africa's Kalahari Desert raised their children. His new book,* The Evolution of Childhood, *is an effort (960 pages, decades in the works) to explain why children everywhere develop, behave, mature and think as they do. Konner, a professor at Emory University, responded by e-mail to executive editor Terence Monmaney's questions.*

How will our understanding of childhood change in the coming decades?

The most impressive findings will come from genetics and brain imaging. Most traits we care about will be influenced by not one or a few but hundreds of genes. Faster and cheaper methods of measurement and analysis will reveal remarkable patterns. Brain imaging has been difficult in infants and children because they don't stay still, but new methods are beginning to compensate for that, and we will know much more about brain function in developing children in real time. This will enable us to separate the aspects of brain function that are maturational and less influenced by the environment from those that respond most readily to nurture and learning. Periods when children may be sensitive to intervention, to the extent that they are important, will be better defined. At the same time, new research will increasingly be driven by hypotheses from evolutionary theory, even more so as Americans' ignorance about evolution is overcome.

How might scientific insights affect our perception of childhood?

When I think about how our basic views have changed in my lifetime, I think: genes being more influential, infants being more competent, teenage brain growth being more dramatic, and powerful environmental interventions being more specific than we thought. Biology will continue to guide intervention, just as figuring out how the metabolic disorder PKU worked on a chemical level enabled us to test all newborns for it and design a diet for affected babies to prevent mental retardation. Sophisticated developmental analysis of conduct disorder has led to school-based psychological interventions that make a huge difference. Understanding teen brain immaturity against the background of rising hormones is changing education and legal practice. Medications like stimulants for attention deficit and hyperactivity are both overprescribed and under-prescribed because we're not good at finding out which child needs them. There will be hundreds more such insights as the complex interplay of biological, psychological and cultural factors is better understood. Some innovative interventions will be in parenting, some in education, some in medicine, some even in play. New discoveries will trounce old ideologies and open all our minds about what to do for children and how to do it.

NO. 24
BRAIN SCANS WILL (FINALLY) ILLUMINATE THE WORKINGS OF THE INFANT MIND.

Is the experience of childhood itself likely to change?

It depends. Sure, it will be great to know more about how to help those children who are already highly privileged to become even better nurtured and educated and turn into ever more effective and happy adults. But scientific advances will matter little without very big policy changes. We already know that it is bad for children to be abused, neglected, ill without treatment, ineptly educated, sexually exploited and enslaved, yet we do so little to combat these scourges—and I am talking, by the way, about problems inside the U.S., not just on the other side of the planet. We need knowledge but we also need will, and we need a moral compass that will lead us to a better environment for all children everywhere.

BRAIN GROWTH **"New research will increasingly be driven by . . . evolutionary theory," says Konner.**

ANN CALE KRUGER

INTERACTION AND ADVENTURE

Artists + digital technology = bold new ways of engaging viewers

BY RICHARD KOSHALEK

WHAT WILL HAPPEN IN THE ART WORLD BY 2050? I predict that all the smashed plates on Julian Schnabel's paintings will fall off on exactly the same day.

Seriously, though, by 2050, I believe that artists will be exploring and affecting all aspects of our daily environment in the most original ways possible. We're already seeing that artists today are moving beyond the four walls of established institutions (such as museums) and are directly engaging and inspiring a range of new audiences. Through new technologies especially, these audiences will grow, as will artists' presence and influence.

NO. 25
EMPOWERED AS NEVER BEFORE, ARTISTS WILL HAVE A SAY IN HOW THE WORLD IS RUN.

At the Hirshhorn, we're organizing two major initiatives for 2012 that reflect this changing dynamic between artists and society. The first is an exhibition, "Animated World," that will dramatically show how the medium of animation has exceeded the wildest dreams of its original film-based creators and is permeating the entire visual landscape around the world. From cellphone screens to urban spaces, animation is increasingly present in our everyday lives and will proliferate in astonishingly inventive ways. Our other project is a major conference called "Open Source," which will explore the effects of new technologies on art, art-making and culture.

We'll also be working with Doug Aitken, a multimedia artist who has a wide view of the world. He's interested in art, architecture, science and the global environmental situation. He's dealing with new media, video and new technology.

Yet despite the focus on new media, we will never abandon our passionate commitment to painting and sculpture. There are always artists advancing these mediums. There is always something new in painting and sculpture. It's just not going to be as straightforward as it has been. In a world changing at warp speed, we will see greater complexity in the types of work produced.

Most excitingly, there will be an increasingly rich dialogue between the artist and the audience. Art is going to reach so many more people and will not be perceived as something

Watch Koshalek discuss the future of art at Smithsonian.com/koshalek

ICON ILLUSTRATIONS: STEVEN NOBLE

Artists will move beyond the "four walls of established institutions" (above: a Doug Aitken video installation projected on the exterior of a Los Angeles-area gallery), says Richard Koshalek (below), director of the Smithsonian's Hirshhorn Museum.

STEVEN A. HELLER / HIRSHHORN MUSEUM AND SCULPTURE GARDEN, SI; PP. 94-95 BRIAN FORREST

"exotic" or marginalized—but rather as a normal mode of existence along with other pursuits. If there's one thing I believe, it's that the primary responsibility of museums is to teach us to live life with greater imagination. The best way to do this is to bring the public into contact with artists in settings that museums are uniquely able to provide.

Art is constantly evolving. Jackson Pollock's seeming spontaneity yet formalism in abstraction changed art forever. Robert Rauschenberg moved us from Abstract Expressionism to Pop and then into new hybrid forms. Because of such breakthroughs and because of new technologies, there is going to be an ever-greater openness in art and art-making. Andy Warhol showed this most dramatically. He explored every medium of his day. He co-founded *Interview* magazine, he produced remarkable films, he explored new applications of traditional mediums such as silk-screening, and, of course, he completely transformed our perceptions of commercial imagery.

In the future, the art world will be even more liberated to make use of all the media around us—because artists have this passionate curiosity and ceaseless desire for new ideas.

By 2050, you're going to see a new leadership equation emerge based on what happens in the art world. Traditionally, decisions have been made by political and corporate leadership. In the future, creative individuals—artists, architects and designers—are going to be making major decisions having to do with how we shape our society, and especially in the world's urban environments, since by 2050 the majority of people will be living in cities.

Ultimately, entirely new types of artists will also emerge from all of this. Artists are, at heart, opportunity-seekers who transform the world around us. They give me tremendous optimism. I believe the future is unknowable, but it is not unthinkable.

RITA DOVE SPEED READING

RAISING THE BAR

Literature, says the poet, novelist and playwright, will look "for different ways to distinguish itself from mass media."

RITA DOVE WAS 41 YEARS OLD WHEN, IN *1993, she became poet laureate of the United States—the youngest person and the first African-American to serve in the post. She has published nine books of poetry, including the 1987 Pulitzer Prize-winning* Thomas and Beulah, *based on her grandparents, and this past year's* Sonata Mulattica. *Dove, who has also written short stories, a verse play and a novel, is Commonwealth Professor of English at the University of Virginia in Charlottesville. She spoke with associate editor Lucinda Moore.*

What is the future of literature?

With the advent of technology and cyberspace and iPads and Kindle, I feel change happening even at the level of composition. In the past, a reader had to rely upon the author to supply all the details of what it was like to hike in Nepal, let's say. Thanks to search engines, now you can quickly look it up, and that's going to change the way literature is written.

How will blogs, YouTube and other technology affect authors?

The intimacy that literature affords—that feeling that you are really in the head of the characters portrayed—used to be almost the private privilege of plays, novels and poetry. Now there's another place that has it—be it blogs, Facebook or Twitter—and it gives you second-by-second accounts. That does not diminish the power of literature, because literature is shaped intimacy. For the writer, it raises the bar, as it should. The very fact that we can be found at any moment, through a cellphone or whatever, changes the way plot will work. How many plots were dependent upon the fact that a note had to be passed here or there or that someone didn't answer the phone?

NO. 26
NOVELISTS WILL RUE THE ABSENCE OF THE UNANSWERED PHONE CALL AS A PLOT DEVICE.

What is shaping literature and its future?

I flash back to Kurt Vonnegut's *Slaughterhouse-Five*, which came out in 1969. It seemed to be a plot that had exploded, which you then had to piece together. It seemed to acknowledge the fact that you couldn't put all the pieces together right away. At the end of the novel, it still felt like it was going on. The acknowledgement that things are going to be playing out beyond the provenance of the work of fiction had some of its seeds right there. I think you see more of a willingness in literature to acknowledge the fact that this is not a perfectly shaped whole, that lives are going to be messy.

Things like the iPad and Kindle will allow us to carry around massive amounts of literature. Because of that, literature is going to be looking for different ways to distinguish itself from mass media, and it's going to feel freer to experiment.

CONTINUED ON PAGE 132

DAMON WINTER / THE NEW YORK TIMES / REDUX

ARTS & CULTURE

40 THINGS TO KNOW

Q&A

TOD MACHOVER MAKE YOUR OWN MUSIC

TOD MACHOVER, CALLED "AMERICA'S MOST *wired composer" by the* Los Angeles Times, *has written six operas, including the robotic* Death and the Powers, *scheduled to debut in Monaco in September. The 56-year-old composer and cellist is the inventor of Hyperscore, a computer program that enables even the untrained to write music, and his students created the popular computer-based toys Guitar Hero and Rock Band. He spoke with the magazine's Erica R. Hendry at MIT, where he's a professor of music and media.*

How is technology democratizing music?

Art can transform people's lives. But it should be available and understandable to everybody. It should be serious but not elitist. Sure, if you want to study for 20 years and become incredibly skilled at a particular musical instrument, that's great. But I can also make an instrument that would allow you right now to take a piece of music and shape it. Hyperscore, which uses lines and colors to allow children basically to draw music, is pretty sophisticated but very easy to use. Kids have fantastic ideas, and if you can get them to try something with a tool like Hyperscore, within 20 minutes you can start to explore what structure is, what it means to tell a story with music. It's democratizing music because it lets everybody make their own music.

How did you end up at MIT's Media Lab?

My mom is a pianist, and a very creative music teacher, and my dad was in computer graphics. So there was music and technology at home. At the end of a piano lesson my mom would say, "Look around the house for something that makes an interesting sound." We'd run around and get a book, a lamp, a pot, a pan. She'd say, "What sound does it make? What's the loudest you can make it? What if you combined it with another sound? Can we make a story out of those sounds?" We'd work like that until we created a piece. Then she'd say, "Can you make a picture of what you just heard so we can play it again next week?" In that little bit of experimentation I learned that music wasn't just something printed, written by dead people you'll never see. Music comes from the world around you. It's ordered by people for particular reasons. Music is a way of telling a story—whether it has characters or not, it has to have a progression.

NO. 27
COMPOSERS WILL NO LONGER BE THE ONLY PEOPLE WHO ARE CAPABLE OF COMPOSING.

Some musicians say people who use technology shortcuts don't understand what they're doing.

There are people who say you couldn't possibly get to an interesting musical experience without paying your dues. I agree that concentration and effort and sustained focus on anything are going to reveal richer and more exciting things you can do. But it's not always so obvious even when you study an instrument for 20 years how to get to the deep part of it. Most of the activities I'm involved with are getting people to the core of musical expression as fast as possible and then setting up an environment where they enjoy it enough to spend days or years getting better at it.

How will music change in 40 years?

Nowadays, composers and performers find the simplest way to make music that appeals to the largest number of people. One way that music will develop is in the opposite direction—creating music that only you respond to, based on our growing understanding of the neuroscience of music. You could share such music with others. But we could fine-tune this personal music to have a specific emotional and a mental effect. Then music could be a tool for pulling someone out of depression or calming them down. Specialists who are partly psychiatrists and partly composers and partly neuroscientists could help create that music and prescribe it, then shape and tweak it during a listening experience for maximum impact. That might be a dream now, but it will soon be possible, and this seems an enormous change in the potential of music to reach us in the most powerful way.

JARED LEEDS

GUITAR HERO

"Kids have fantastic ideas," says "wired composer" Machover (with an instrument from the Beatles version of Rock Band, the computer-based musical toy invented by his students at MIT).

THE FUTURE OF HISTORY

Archives opening in coming decades will shed new light on pivotal 20th-century figures and events **BY MARK STRAUSS**

THE PAST LOOKS QUITE PROMISING. OVER THE NEXT several decades, governments and universities will shed new light on historic figures and events by opening long-sealed archives.

Take the Harvard University Archives, which, in 30 years, will unseal John F. Kennedy's responses to questionnaires and psychological tests he was first given as an undergraduate. Robert Dallek, a historian and author of the JFK biography *An Unfinished Life*, speculates that the papers could reveal fresh insights into the 35th president's character. "Did he have any focus on social issues as a young man?" Dallek wonders. "Or maybe there will be a picture of a very vacuous young man, preoccupied with his self-indulgences, because that was another side of him."

NO. 28

IN 2040, SECRET DOCUMENTS WILL TELL SCHOLARS IF THE YOUNG JFK WAS "VACUOUS."

Keeping in mind that history never ceases to be rewritten, here is a collection of must-know archives scheduled to open in coming decades:

2011: The State Department's Office of the Historian expects to begin releasing volumes on Nixon and Ford administration foreign policy initiatives, including potentially new details on the energy crisis, NATO and the 1973 Arab-Israeli War.

2019: The papers of the poet T. S. Eliot, who died in 1965, include 1,200 personal letters that have remained off-limits: his correspondence with Emily Hale, a girlfriend whom biographer Lyndall Gordon described as Eliot's "muse." In 1959, Hale bequeathed the letters to Princeton University.

2026: As chief justice of the United States from 1969 to 1986, Warren Burger presided over cases concerning abortion, capital punishment and the Watergate scandal. In 1996, the year after Burger died, his son, Wade, donated the justice's personal papers—some two million documents—to the College of William & Mary in Williamsburg, Virginia, with the understanding they would be sealed for 30 years.

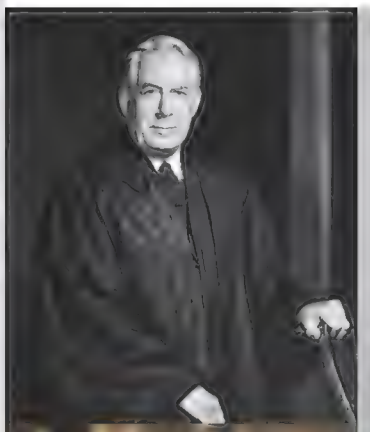
2027: The FBI spied on Martin Luther King Jr. in an unsuccessful effort to prove he had ties to Communist organizations. In 1963, Attorney General Robert Kennedy granted an FBI request to surreptitiously record King and his associates by tapping their phones and placing hidden microphones in their homes, hotel rooms and offices. A 1977 court order sealed transcripts of the surveillance tapes for 50 years.

2037: A decade ago, Oxford University's Bodleian Library released ten boxes of documents pertaining to the 1936 abdication of Edward VIII so that he could marry American divorcée Wallis Simpson. But one collection of "sensitive documents" (Box 24) was to be withheld for 37 years. British news media speculate the documents include embarrassing revelations about the Queen Mother's alleged support for negotiating peace with Nazi Germany prior to the outbreak of World War II.

2040: Psychiatrists initiated the Harvard Study of Adult Development in 1937 to track the lives of 268 men who'd recently entered college. The ongoing study uses questionnaires, interviews, psychological tests and medical exams to better understand what contributes to mental and physical well-being. The identity of most of the men is unknown, but reportedly they include a best-selling novelist and four candidates for the Senate. (Former *Washington Post* editor Ben Bradlee admitted to being a participant in his 1995 autobiography, *A Good Life*.) John F. Kennedy's file—containing questionnaires and reports from 1940 until his death in 1963—was withdrawn from the study's office, not to be unsealed for 30 years.

2041: Deputy Führer Rudolf Hess flew from Germany to Scotland on May 10, 1941, claiming that he wanted to discuss peace terms with Britain and that their common enemy was the Soviet Union. Hess was imprisoned and interrogated. After the war, he was convicted at the Nuremberg trials and sentenced to life at Spandau Prison. A British intelligence file said to contain an interrogation transcript and Hess' correspondence with King George VI is scheduled to be unsealed 100 years after his arrest. Historians say the papers might show whether British intelligence tricked Hess into undertaking his fateful mission.

P. 99 AFP / GETTY IMAGES; BACHRACH / GETTY IMAGES; REG LANCASTER / EXPRESS / GETTY IMAGES; AP IMAGES; HULTON ARCHIVE / GETTY IMAGES; CENTRAL PRESS / GETTY IMAGES; GRANGER COLLECTION, NEW YORK; TIME LIFE PICTURES / GETTY IMAGES; BETTMANN / CORBIS



Clockwise from top left: With archives still to open, historians look to learn more about foreign policy under Richard Nixon (with Israel Prime Minister Golda Meir in 1973); Chief Justice Warren Burger (top); T. S. Eliot's love life; FBI surveillance of Martin Luther King Jr.; England's Queen Mother (in 1940); the psychological tests taken by student John F. Kennedy (in 1938); Deputy Führer Rudolf Hess; a U.K. program to hunt Nazi subs; and an accidental bombing by the Royal Air Force.

2045: In May 1945, the British Royal Air Force (RAF) attacked two German ships in the Baltic Sea carrying 7,000 survivors of the Neuengamme concentration camp. Only 350 survived. RAF intelligence had mistakenly believed the vessels held Nazi officials escaping to Norway or Sweden. Because the RAF ordered the records to remain classified for 100 years, scholars have been unable to offer a complete account of one of the worst "friendly-fire" incidents in history.

2045: During World War II, the Royal Canadian Air Force (RCAF) lent Britain highly skilled radar technicians—"the Secret 5,000"—who flew on patrols over the Atlantic Ocean to detect German submarines and aircraft. The RCAF deemed its work so classified it sealed all pertinent records about the operation for a century. Even today, the Secret 5,000 are not mentioned in official RCAF histories.

MARK STRAUSS *is a senior editor at* SMITHSONIAN.

ARTS & CULTURE

40 THINGS TO KNOW

Q&A

JAMES CAMERON MOVIES GET DEEPER

NO. 29

THE MAN BEHIND HOLLYWOOD'S TOP-GROSSING HITS WILL STILL BE MAKING MOVIES AT 96.

MANY BELIEVE THAT *AVATAR*, THE LARGELY *computer-generated, 3-D film by James Cameron—and the top-grossing movie in history, earning nearly $3 billion worldwide—has changed the moviegoing experience. Like* Avatar, *Cameron's 1984 thriller* Terminator, *about an indestructible human-machine cyborg, and 1997's* Titanic, *with its hyper-realistic feel for the "unsinkable" ship's disastrous end, are morality tales about technology's risks—created with the most advanced technology. The director spoke with reporter Lorenza Muñoz.*

How has technology evolved since your first foray into film?

Terminator was my first real film, and you can directly contrast 1984 to 2010. No single technique we used then was used today. We shot *Terminator* on film, and we don't shoot on film today. All of the visual effects are digital now. Back then we used glass paintings, foreground miniatures and stop-motion animation. We thought we were being tremendously innovative—and we were. The technology has changed but the basics of the job haven't. It is still about storytelling, about juxtaposing images, about creating a feeling with images and music. Only the technical details have changed.

How do you see technology changing for the *Avatar* sequel?

We always planned to make this as a series of two or three movies. The appeal of going into the second film is that we can continue with the system we created. Now we will just speed it up, refine and make it more intuitive for the artists working on the film. The next movies will be more about details but not fundamentally different.

In 40 years, will people see movies in theaters, or will everyone be watching from home on computers with 3-D capacity?

I think there will be movie theaters in 1,000 years. People want the group experience, the sense of going out and participating in a film together. People have been predicting the demise of movie theaters since I started in the business.

Why doesn't the *Avatar* DVD have 3-D?

We have to wait until the technology is available in every home. I think it will be standard in 4 years, not 40. We will have a glasses-free technology in five years at home and three years for laptops. The limiting factor is going to be content. You can't rely on a few films a year for this. It is going to have to be 3-D broadcast sports, scripted television, non-scripted television and reality television.

Will Hollywood still be the filmmaking capital of the world in 40 years?

It will always be a filmmaking center. Filmmakers from China and Japan and Germany come to Hollywood to have meetings with studio executives and to get money for their movies. It is a central switching station for global entertainment. Hollywood is also the place for filmmakers who want to make movies for a global market. China and Russia make films for their own markets, but I don't see the likelihood of those places replacing Hollywood. India has a huge film industry that supplies hundreds of films a year, but it is very much about that market.

Will you be making movies in 40 years?

If I'm alive. I will be 96, so I will be making films very, very slowly.

STORYTELLING

Cameron is in command (with *Avatar*'s Sigourney Weaver, Joel Moore and Sam Worthington).

20TH CENTURY FOX / EVERETT COLLECTION

GEORGE LOPEZ COMEDY WISES UP

ON HIS NIGHTLY TALK SHOW, "LOPEZ *Tonight," on his HBO specials and at clubs and auditoriums, the comedian George Lopez takes aim at ethnic stereotypes. In a recent monologue, he noted that babies born to minorities will soon outnumber babies born to whites in the United States. "You'll have to learn to clean your own house!" he joked (to whites). Some audience members booed. When his ABC sitcom, "George Lopez," was canceled in 2007 after six years and replaced by "Cavemen," he blasted network executives. "So a Chicano can't be on TV," he said, "but a cave man can?" His angry-young-man reputation has been softened by charitable works, including a foundation he started with his wife, Ann. He received Harvard University's Artist of the Year award in 2004 for "humanitarian efforts to prevent youth violence and support community arts resources and education." Lopez was interviewed by Lorenza Muñoz, a journalist in Los Angeles.*

Where do you see comedy headed in the next 40 years?
I see it changing by having the comedy club come to your house. Everything will be seen on your computer or BlackBerry or whatever devices we will be seeing in the future. Comedians will put their content on whatever server and send it to you specifically. We may even lose the live performance.

What was it like when you started out?
A club used to be like your house, where you could say something and it would stay there. I saw people bomb, get in fights, walk off the stage, people getting kicked in the face, and it all stayed in the club because nobody was taping them. Now with BlackBerrys and iPhones and iPods, whatever is said at a club can be seen around the world.

How will comedy change in 40 years?
Comedy will become more diverse, more political. There will be more taped pieces and personal pieces. I don't know if the art of stand-up will survive. Stand-up seems dated. Now you can do a mini-movie or a short with a beginning, middle and end. A guy standing there seems a little old—especially when you can go on the Internet and see Funny or Die.

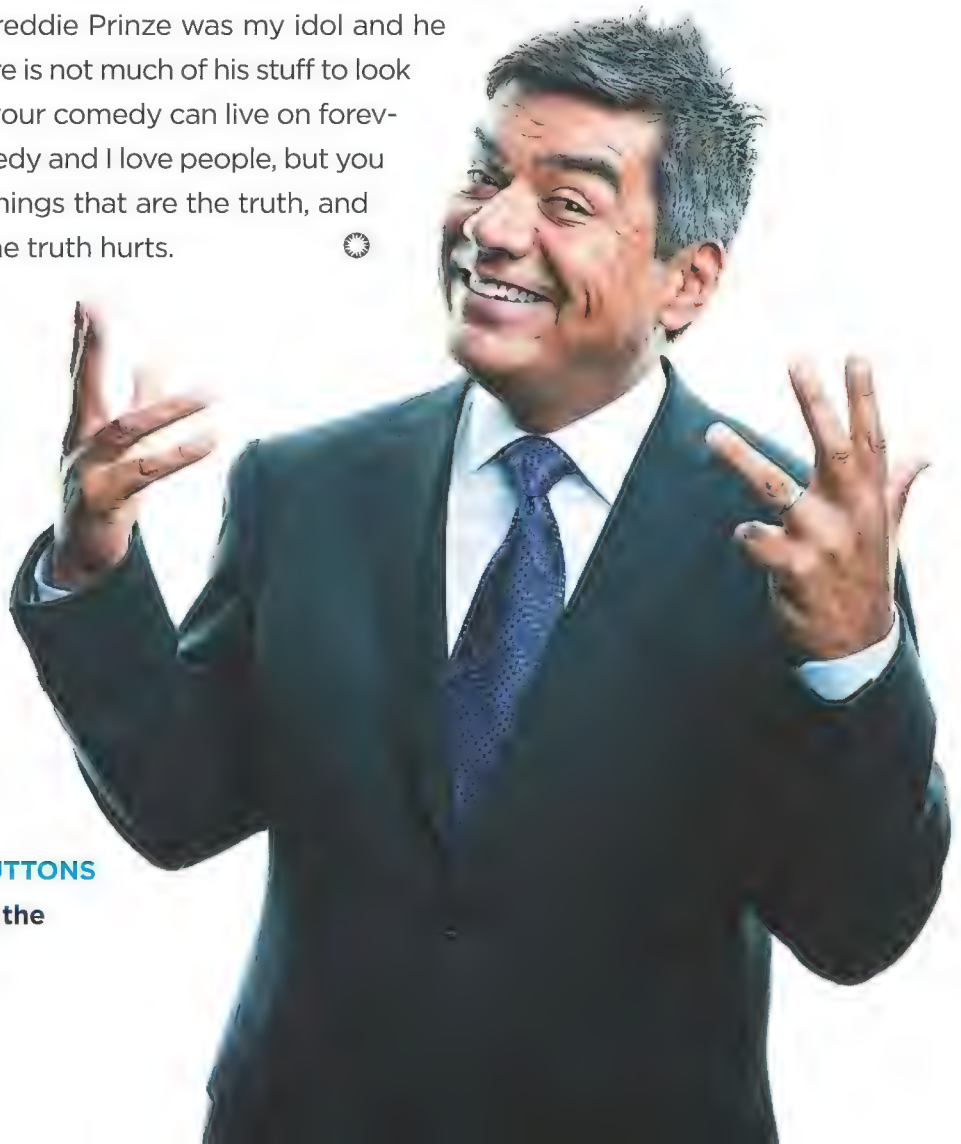
How has race and ethnicity changed in comedy?
If you look back in time, comedy was always insensitive to people of color because our country, and comedy, was dominated by whites. That is why Amos and Andy could paint their faces black and make "black" voices and everyone in the theater who was white thought it was hilarious. You can't do that anymore. Then there was "All in the Family" or "Sanford and Son" or "The Jeffersons." Then we got overly sensitive and politically correct. But you can still do [ethnic and racial comedy] if you tell the truth. If you do it out of meanness, it's no fun.

Do you think race and ethnicity will be an issue in 40 years?
Hopefully we won't be as cynical and mean as we are now. Twitter and MySpace sometimes feed people's dark sides.

NO. 30
WHAT TECHNOLOGY WILL DO TO STAND-UP COMEDY ISN'T FUNNY.

Have you been surprised by the way technology has made you known all around the world?
Yes. I was in Europe on vacation and this 14-year-old Israeli kid wanted to take his picture with me. I get mail from the Netherlands and South Africa and India and Australia. Carlos Santana told me that to think of yourself as a citizen of the U.S. is narrow. You have to think of yourself as a citizen of the world. You should be global.

Will you still be doing comedy in 40 years?
Hell, no! I am not going to be some 88-year-old dude wandering around like that. I will live forever, though. Freddie Prinze was my idol and he died, and there is not much of his stuff to look at. But now, your comedy can live on forever. I love comedy and I love people, but you have to say things that are the truth, and sometimes the truth hurts.



KEVIN SCANLON / THE NEW YORK TIMES / REDUX

PUSHING BUTTONS
"Sometimes the truth hurts."

POWWOWS AND KARAOKE

The movie director, descended from Southern Cheyenne and Arapaho peoples, says Native pride will

"OOOOH, LOOK AT THAT!" SHAHELA EXCLAIMS.

My daughter and I watch in fascination as an enormous grayish-purple cloud sweeps over the golden-brown rolling hills of the plains, cascades through the expansive sky and merges with the yellow horizon.

At that moment, I'm awe-struck by the power of the season changing from winter to spring, and I realize the spectacle would not be as beautiful without the dark gray cloud on the horizon.

I'm always inspired by the rebirth of the seasons. After I was born to my biological mother, Rose, of the Southern Cheyenne and Arapaho tribes, I was reborn within days to my adopted parents, Barb and Earl, in a white middle-class home in Klamath Falls, Oregon. As a dark-skinned 5-year-old, I would ask my mom what I was going to be when I grew up.

"Anything you want!" she said.

"A fireman?"

"Yes!"

"What about president?"

"Yes!" she lied, lovingly. Or perhaps she had the foresight 30 years ago to think there would be a minority president.

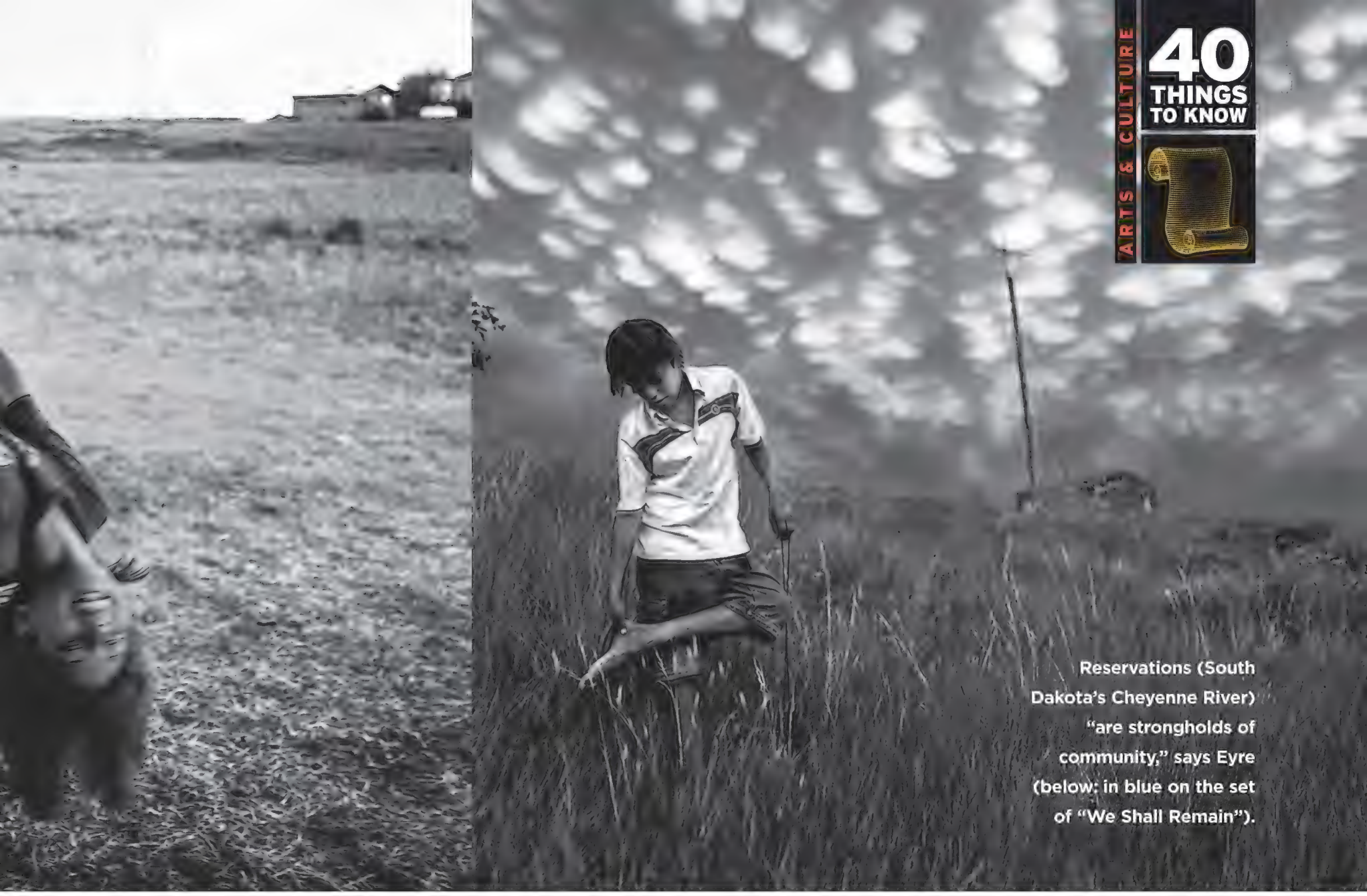
NO. 31
NATIVE AMERICAN YOUTHS WILL SPARK A REVIVAL OF THEIR CULTURE.

As a Native American raised in a white environment, I have never seen things in black and white but always in many colors and shades of gray. I love singing country and western songs at karaoke, but I also love a good powwow and fry bread. Over the years, my work as an artist has always been about bridging the gap between the white world and the Native world. I then realized that it had already been done. There have been "Indian rednecks" for years.

I came to appreciate through my work that there are good people in both the Native and non-Native world. Though I also found that the American dream usually didn't include my people, the Natives. For example, religious freedom for Natives to practice their own traditions was not legally upheld until 1994.

In the next 40 years, the greatest threat to Native tribal culture and tradition will be the American consumer ethic of personal economic gain at all costs. It runs deeply counter to the spirit of giving and codependence that is central to what we are as a people.

As more Native Americans participate in the wider econ-



Reservations (South Dakota's Cheyenne River) "are strongholds of community," says Eyre (below: in blue on the set of "We Shall Remain").

BOTTOM RIGHT: AMERICAN EXPERIENCE / WGBH

embolden the next generation of the first Americans **BY CHRIS EYRE** PHOTOGRAPHS BY EMILY SCHIFFER

omy through business initiatives such as gaming, we will also struggle with assimilation, a force that we have fought over the years. It was only about 20 years ago that the public at large allowed Indian gaming as a way to give back to the Indians. Ten years ago, I remember seeing a Native kid at a Southern California powwow driving his parents' Hummer. A minority of tribes and their reservations have prospered from Indian gaming, but most still live in the same dire conditions.

Marginal cultures in the past have rightfully entered the mainstream through business, taking money from the majority and infusing it into their own tribes. It happened with Latinos, Asians and now Natives. It's the American way. My greatest fear is that after all these years largely as nonparticipants in the American dream, our inclusion will ultimately kill off tribal languages, traditions and our knowledge.

Today, it is inspiring to see the number of strong Native American youth eager to learn more of our ancient traditions and cultures from the elders, who are more than happy to share with those who respect them. The youth renaissance is rooted, I think, in the elders' tenacity, 1970s activism and a backlash against the mass media's depiction of Native Americans.

The dismal portrayal of Native reservations is inaccurate and harmful. The media focus solely on poverty and the cycle of oppression. What most outsiders don't see is the laughter, love, smiles, constant joking and humor and the unbreakable strength of the tribal spirit that is there. Some reservations are strongholds of community, serving the needs of their people without economic gain but with traditions leading the way. My hope is that Native evolution will be driven by a reinforced traditionalism passed down from one to another.

There is a calling not taught in religion or school; it is in one's heart. It is what the tribe is about: to give to the cycle; to provide for those older and younger. My daughter knows it, just as she knows the natural beauty of seeing the clouds coming in the spring.

I love the gray rain.

CHRIS EYRE *directed 1998's* Smoke Signals *and three films in the 2009 PBS series "We Shall Remain."* **EMILY SCHIFFER** *founded a youth photography program on the Cheyenne River Reservation.*

ARTS & CULTURE

40 THINGS TO KNOW

Q&A

SABIHA AL KHEMIR ISLAM AND THE WEST

AN AUTHORITY ON ISLAMIC ART, SABIHA AL *Khemir, who was born in Tunisia and lives in London and New York City, has curated exhibitions at museums around the world, seeking to build understanding between Islamic and Western cultures. Her second novel,* The Blue Manuscript, *was published in 2008. She spoke with Amy Crawford, a Pittsburgh-based reporter and a former* SMITHSONIAN *staff member.*

NO. 32
RELATIONS BETWEEN THE UNITED STATES AND THE MUSLIM WORLD WILL IMPROVE.

A NEW BEGINNING
"I believe things are changing, on both sides."

In what ways are people in Islamic and Western cultures the same without realizing it?
I look at my nieces and nephews in Tunisia and at young people here in America. Their outlook is very similar; yet, because of things that have separated us, especially in the last decade or so, the youngsters would talk as if they are completely different. I think youth is youth, it wants similar things—to have fun, to explore the latest technology, to push oneself to the limit, to have freedom.

What misconceptions do Westerners have about Islamic art?
Most people from the Western world would think that imagery is forbidden in Islam and that Islamic art is in fact geometry—the arabesque. But if we look at Islamic art from the seventh century to the present day, in all media—ceramics, glass, painting, metalwork—and across the world, from Syria and Iraq to China, all Islamic art has figurative representation. It is not allowed in a religious space, but it is not forbidden in secular space.

Do you think the strained relationship between the United States and the Muslim world will improve over the next few decades?
There is absolutely no choice but for it to improve. It's the only way forward, because if it doesn't, there will be no future. I believe things are changing, on both sides. The East is no longer far away. Also, this new generation, in various parts of the Islamic world, they are modern in thinking and modern in seeing the world. With all the communication that's happening and all the opening of boundaries, the connections are there. As you cross the world, it's amazing. I've done a book tour in this country for *The Blue Manuscript*. It was fascinating how much people are open and want to know. That curiosity wasn't there so much a decade ago, 20 years ago. . . . People want to know, because they realize quickly enough that the way Islam has been represented by a certain minority, extremism, et cetera, is not necessarily Islam the way it is. I am traveling around America seeing museum collections, in search of Islamic art pieces. Whether it is in the work environment, as we look at the pieces, or whether it is over dinner or lunch, people are talking about the Islamic world.

What has furthered the cause of understanding?
One of the turning points was [President] Obama's speech in Cairo [in 2009, titled "A New Beginning"]. It made America position itself in a completely different way vis-à-vis the

CONTINUED ON PAGE 134

GINA LEVAY / REDUX

CARL HIAASEN SLIPPING BACKWARD

AS A *MIAMI HERALD* COLUMNIST AND THE *author of a dozen satirical novels, including the forthcoming* Star Island, *Carl Hiaasen has compiled a body of work populated by venal real estate developers, crooked politicians, environmental zealots, dead tourists, ambitious strippers and numbskull lowlifes. He says that as nonfiction has gotten stranger than fiction, it's become harder for a satirist to stay ahead of "the curve of human weirdness. America is becoming more like South Florida every day, which is terrifying." Hiaasen, 57, divides his time between Vero Beach and the Florida Keys. He spoke with senior editor T. A. Frail by phone.*

Isn't it possible we could just get off the weirdness curve and return to a more civilized state?
No, it's not. When I go out and give speeches, the title of my speech is "The Case Against Intelligent Design." And I base it strictly on what I've observed here in Florida, which is that the human race is actually de-evolving, that we are moving backward on the evolutionary scale. If you picked the headlines from the five largest newspapers in Florida every day, you could make a very solid case that the human race was slipping backward into the primal ooze. The species has not been elevated by much of what's happened in the last 30 or 40 years. And obviously, it's not just in Florida. The sort of thing that used to happen only in fiction can hardly compare to what's in the news today. The reality of our current politics and the economic meltdown—that's straight out of Tom Wolfe.

What fresh outrages do you fear are going to happen in the next 40 years?
For one thing, the level of political discourse will only get nastier. The Supreme Court's decision to let corporations pour as much money as they want directly into political advertising—and do it anonymously—is toxic to the whole democratic process. From now on, it's basically going to be all the free speech that money can buy.

Do you see an antidote?
Public outrage is the best antidote, because it often leads to change. But people can't get outraged without rapid access to solid, useful information—what we used to call journalism. There's so much garbage being disguised as fact and so many gasbags posing as sages; somebody has to cut through the crap. That's the job of reporters, and their job will be more important than at any time in history. There's been this great lamentation about the end of newspapers as we know them, the end of the era of the paper hitting your doorstep in the morning, but I don't think the language or the craft of writing is dying. In the next 40 years, there's going to be a larger demand than ever for people who can communicate with the written word, whatever format it takes. I don't think there's ever been a greater need for people to be able to write at a functional level, whether they're tapping on their computer keyboard or on their iPhone.

NO. 33
IN PARTS OF THE UNITED STATES, HUMAN EVOLUTION MAY EVEN REVERSE ITSELF.

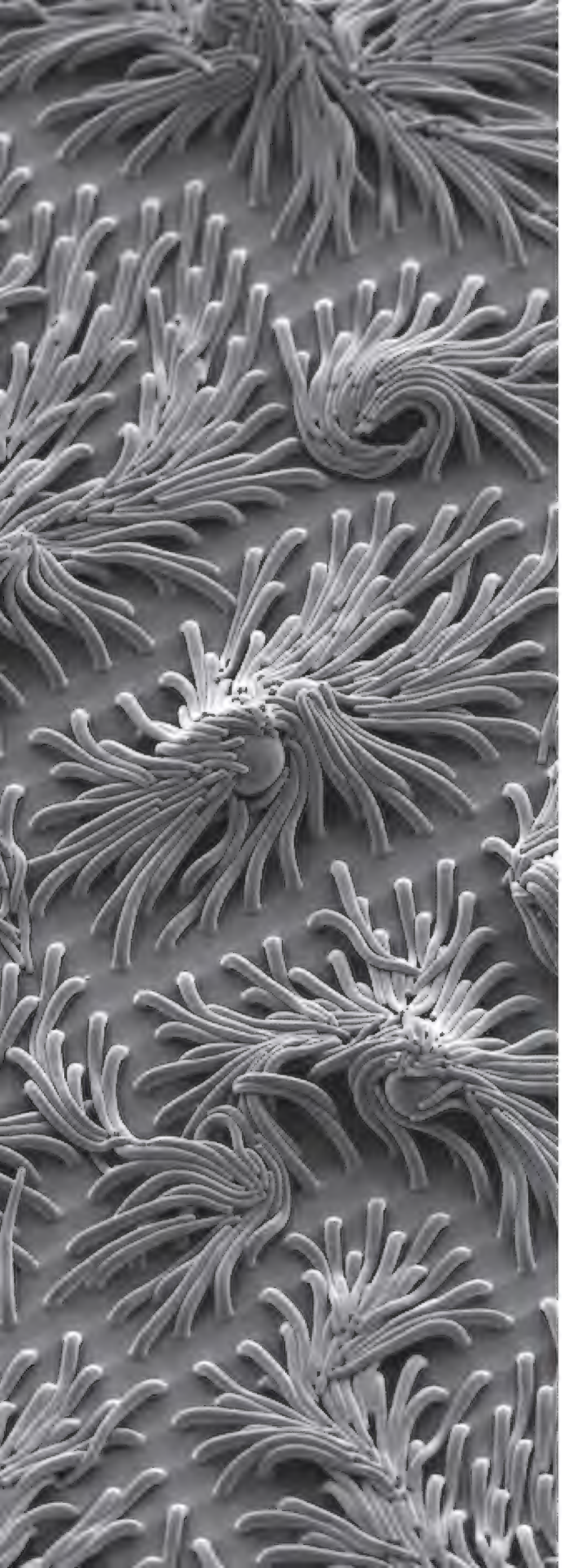
BRIAN SMITH

FLORIDA SON
The human race "has not been elevated" over the past 40 years, Hiaasen says. "The sort of thing that used to happen only in fiction can hardly compare to what's in the news today."

THE GENIUS OF SMALL THINGS

If George Whitesides thinks nanotechnology can save lives, you better believe it

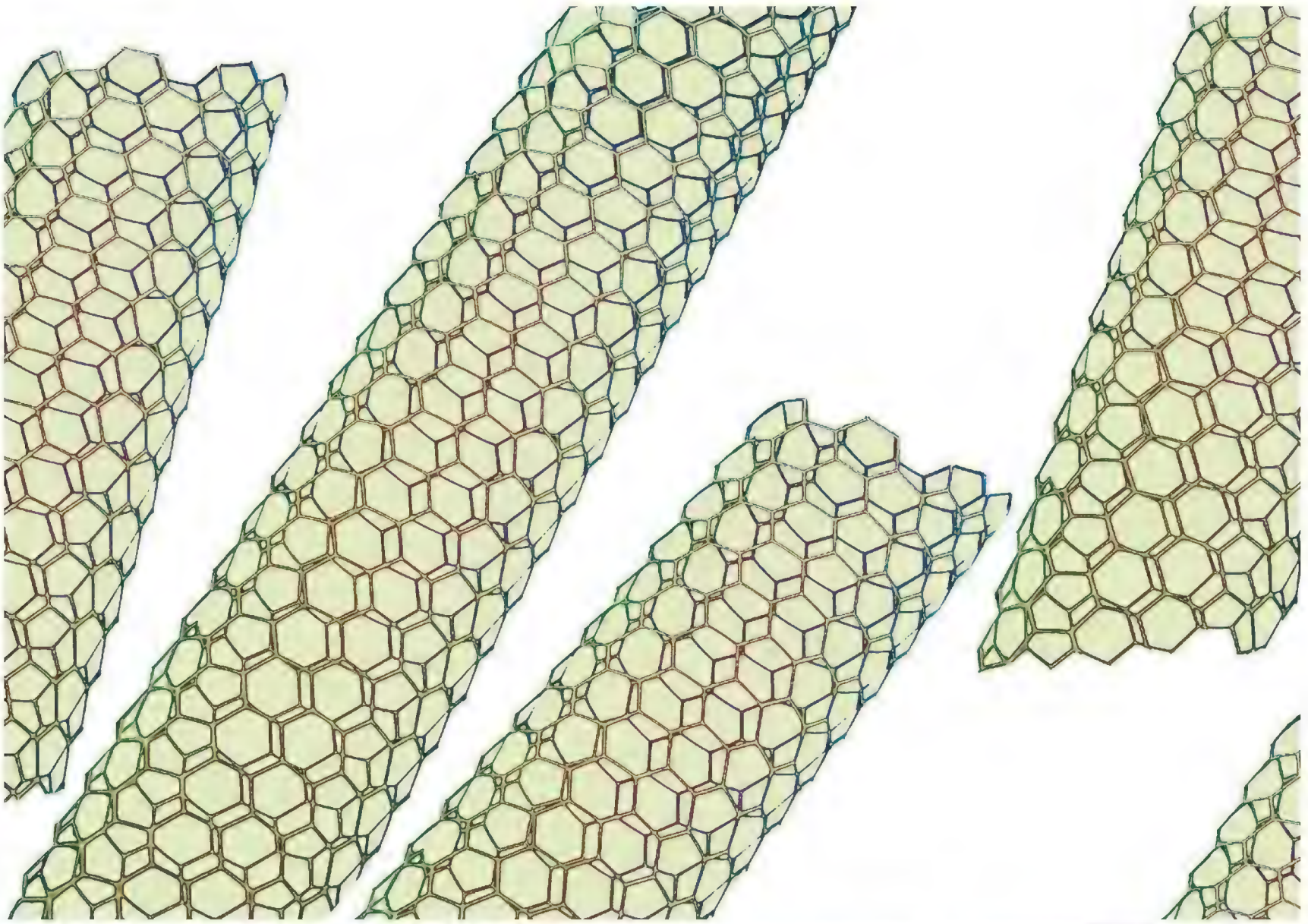
BY MICHAEL ROSENWALD



FINDING GEORGE WHITESIDES IS OFTEN TRICKY EVEN for George Whitesides. So he keeps an envelope in his jacket pocket. "I don't actually know where I am in general until I look at it," he says, "and then I find that I'm in Terre Haute, and then the question really is, 'What's next?'" During a recent stretch, the envelope revealed that he was in Boston, Abu Dhabi, Mumbai, Delhi, Basel, Geneva, Boston, Copenhagen, Boston, Seattle, Boston, Los Angeles and Boston.

The reason Boston shows up so frequently, although not as often as his wife prefers, is that Whitesides is a professor of chemistry at Harvard University, and Boston Logan is his home airport. The reason for all the other cities is that Whitesides' contributions to science range into biology, engineering, physiology, materials science, physics and, espe-

At very small scales, the most common materials "turn out to be so alien," says Whitesides (above: with a prototype of a diagnostic chip; left: polymer fronds a few thousand nanometers long wrap around even tinier polymer spheres).



FELICE C. FRANKEL (2), PP. 106-107 FELICE C. FRANKEL, P. 107 PAULA LERNER / AURORA SELECT, ICON ILLUSTRATIONS. STEVEN NOBLE

cially these days, nanotechnology. Other scientists, government leaders, inventors and investors worldwide want to hear from him.

Whitesides' inventions and ideas have spawned more than a dozen companies, including drug giant Genzyme. No Harvard lab comes close to matching the number of patents attached to his name—"approximately 90," he says. The citation "GM Whitesides" shows up more frequently in academic papers than that of nearly any other chemist in history.

So Whitesides is something like the Bono of science, though taller, more wiry and at age 70, less hirsute. A Scottish fisherman's cap almost always covers his head, even in front of an audience. He has a deep voice, with little hint of his native Kentucky. Lately that voice has been introducing audiences to a new nanotechnology project aimed at saving lives in the developing world. "What is the cheapest possible stuff that you could make a diagnostic system out of?" he asks. "Paper."

On a piece of paper no thicker or wider than a postage stamp, Whitesides has built a medical laboratory.

ONE DAY THIS PAST WINTER, Whitesides woke up in his own bed. By 9 a.m. he was in his office just off Harvard Yard. He wore his typical outfit: a pinstripe suit, white shirt, no tie. He set his fisherman's cap on a conference table in front of a bookshelf that held *The Cell*, *Microelectronic Materials*, *Physical Chemistry*, *Advanced Organic Chemistry* and *Bartlett's Familiar Quotations.*

NO. 34
A MEDICAL LAB THAT FITS ON A POSTAGE STAMP WILL SAVE LIVES IN THE WORLD'S POOREST AREAS.

A text not on the shelf was *No Small Matter: Science on the Nanoscale*, a newly published coffee-table book by Whitesides and the science photographer Felice C. Frankel. It's about truly exotic things that appear to be very large but are exceptionally, absurdly, *astoundingly* small—nanotubes, quantum dots, self-assembling machines.

Nanotechnology is, simply defined, the science of structures measuring between 1 nanometer, or billionth of a meter, and 100 nanometers. (The prefix "nano" comes from the Greek word for dwarf.) Still, to most people, that definition isn't so simple. Trying to understand nanometers can rapidly induce crossed eyes. The sheet of paper these words are printed on is 100,000 nanometers thick—the diameter of a human hair, roughly the smallest object a person can see with unaided eyes. A bacterium sitting atop this paper is about 1,000 nanometers in diameter—microscopic. To see something only one nanometer in size was impossible until 1981, when two IBM physicists invented the first scanning tunneling microscope. Conventional microscopes use lenses to magnify whatever is in the line of sight. But scanning tunneling microscopes work more like a person reading Braille, moving across the surface of structures by using a tiny stylus. The physicists, who won a Nobel Prize a mere five years later, built a stylus with a tip that was just one atom across (less than one nanometer). As it moves, the stylus detects the material's structure by recording electrical feedback, and then the microscope translates the recordings into images.

Now that really small things—right down to individual atoms—could finally be seen, Whitesides and other chemists got very interested in nanoscale materials. And what they learned amazed them. Materials this small, it turns out, have unexpected properties—we were just clueless until we could see them up close. Molecules with different surfaces—surfaces that don't usually combine well, if at all—can suddenly bind. Glass, normally an insulator of electric currents, can conduct electricity. Materials that could not carry electric charges suddenly become semiconductors. The metal gold, in small enough particles, can appear red or blue.

"One of the fascinations of small things is that they turn out to be so alien, in spite of superficial similarities in shape or function to larger, more familiar relatives," Whitesides writes in his book. "Discovering these differences at the smallest scale is wonderfully engrossing, and using them can change (and has changed) the world."

Scientists have created carbon nanotubes, hollow cylinders two nanometers or less in diameter, that turn out to be the strongest material in the world, 100 times stronger than steel with one-sixth the weight. They've created nanoparticles—less than 100 nanometers wide and useful for very precise biomedical images. Scientists have also made nanowires—silicon threads 10 to 100 nanometers wide and capable of converting heat to electricity. Electronics manufacturers say nanowires could make use of waste heat from computers, car engines and power plants.

Already, more than 1,000 consumer products use some form of nanotechnology (even though a 2008 report from the National Academy of Sciences urged better monitoring of potential health and environmental risks from nanotechnology). The products include stronger and lighter bike frames, fabric treatments that deflect liquids, sunscreens that repel sunlight better, memory cards for computers, and fog-resistant coatings for eyeglass lenses.

Scientists are developing nanoparticles that can deliver just the right amount of medicine to kill a tumor but nothing else around it. Other nanoparticles can detect mercury contamination in water; one day the particles may be used in filters to remove the toxic metal.

Carbon nanotubes (opposite top: a computer-generated model) are the strongest and stiffest materials ever created—even though the tubes' carbon atoms are held together by the kinds of chemical bonds found in pencil lead. Strange nanoscale structures called "quantum dots" emit colored lights and do not fade (opposite bottom: quantum dots dye structures in cells).

The big, life-changing stuff made from little stuff is still ahead of us. Things like batteries that can last months and power electric cars, made from nanowires built by viruses—Angela Belcher at MIT is working on that, and President Obama is so excited by the technology that he has met with her. (See "Invisible Engineers," p. 111.) A Hewlett-Packard lab, led by nanotech visionary Stan Williams, just announced a partnership with Shell to develop ultrasensitive devices to detect oil; in principle, they can register nanoscale shifts in the earth caused by movements in oil fields. Williams calls the product a "central nervous system for the earth."

The prospect of the world fundamentally changing because of nanotechnology is still more dreamy than real, but to experts the possibilities seem almost endless. Scientists have created nanostructures that can self-assemble, meaning they can form into bigger objects with little or no outside direction. Someday these minute objects could, theoretically, build themselves into a machine that makes more nanoparticles. Already, IBM uses self-assembly techniques to produce insulation in computer chips. A center at MIT called the Institute for Soldier Nanotechnologies is working on indestructible battle armor that can react to chemical weapons.

"Everywhere you look," Whitesides says, "you see pieces, and they're all pointing in different directions."

Simple and cheap is what Whitesides wants his nanotechnology inventions to be (above: a lab on a paper stamp that can be used to test liver function).

WHITESIDES DOESN'T KNOW exactly how he got here. Here being Harvard, this lab, this life. Growing up in a small Kentucky town, the son of a homemaker and a chemical engineer, he stuck out at school. One day, a teacher called his parents and said he'd like to talk with them about their son. Their hearts sank. "'What's the little bastard done now?'" Whitesides recalls of his parents' reaction.

The teacher said, "You've got to get your kid out of here. I've arranged for him to go to Andover."

"I had never heard of Andover," Whitesides says now of the elite Massachusetts prep school. "I didn't even know what it was. I didn't know where New England was."

And then, somehow, he ended up attending Harvard. "I don't even remember having applied here. I just got a letter at some point admitting me. So I suppose I came here by accident."

He went on to do graduate work at the California Institute of Technology. In the acknowledgements section of his doctoral dissertation he thanked his adviser, John D. Roberts, for "his patient direction and indirection." Most graduate students value a mentor's direction, Whitesides says. "In my case, he didn't direct me at all. I don't think I saw him in the years I was there, but we had a nice relationship."

Whitesides taught at MIT for nearly 20 years before arriving in 1982 at Harvard, where he is something of a rarity. He is a practicing capitalist, for starters. That focuses him on real-world applications, something not all of his colleagues admire, according to Mara Prentiss, a Harvard physics professor who teaches a nanotechnology course with him. "George is greatly admired by many people, but not everyone appreciates his style," she says. Whitesides doesn't seem to care. "I presume it's out there," he says of any animosity. But he has very little time for those who think that appearing on CNN or starting companies is gauche. He says they can "just take a knitting needle and put it here"—he points at his nose—"and shove it."

Tom Tritton, president of the Chemical Heritage Foundation, a history and educational organization in Philadelphia, says if you ask anyone in the field to list the world's top three chemists, Whitesides will make every list. "The sheer breadth of his intellect is astounding," Tritton says. After receiving the foundation's highest award, the Othmer Gold Medal, Whitesides spent the day with high-school students in the city. Tritton says one student later offered this observation: "He may be a scientist, but he's really cool."

AT THE HEART OF ALMOST everything Whitesides does is a contradiction: he works in complex fields of physics, chemistry, biology and engineering, using complex tools—not many people have ever wielded an atomic force microscope—and yet he is obsessed with simplicity. Ask him for an example of simplicity, and he will say, "Google." He doesn't mean you should Google the word "simplicity." He means the Google home page, the spare rectangle on the white field into which millions of people type words to

PAULA LERNER / AURORA SELECT

find information on the Internet. Whitesides is mesmerized by this box.

"But how does that work?" he says. He pauses, drawing a breath. He leans forward in his chair. His eyes get big. His forehead goes up, and with it his very large glasses. This is George Whitesides getting excited.

"You start with binary, and binary is the simplest form of arithmetic," he says of the system of ones and zeros used to program computers. Then he launches into an impromptu historical guided tour of switches, transistors and integrated circuits before returning, finally, to Google, "which takes an idea of such incredible complexity—to organize all of humanity's information—and puts it in this little thing, in a box."

The idea behind Google—boiling down vast stores of knowledge into an elegant little package—is also the idea behind the thing Whitesides is now holding in his hand, a so-called lab on a chip no bigger than a postage stamp, which is designed to diagnose a variety of ailments with nearly the precision of a modern clinical laboratory.

It's intended for health workers in remote parts of developing nations. They will place a drop of a patient's blood or urine on the stamp; if the ailment is one of the 16 or so that the stamp can recognize, it will change color according to the affliction. Then the health worker, or even the patient, can take a picture of the stamp with a cellphone. The picture can be sent to a doctor or a lab; someday a computer program might allow the cellphone itself to make a tentative diagnosis.

"To treat disease you have to first know what you're treating—that's diagnostics—and then you have to do something," Whitesides says in a standard speech he gives about the technology. "So the program that we're involved in is something which we call diagnostics for all, or zero-cost diagnostics. How do you provide medically relevant information at as close as possible to zero cost? How do you do it?"

You start with paper, he says. It's inexpensive. It's absorbent. It colors easily. To turn paper into a diagnostic tool, Whitesides runs it through a wax printer. The printer melts wax onto the paper to create channels with nanometer-size molecules at the ends. These molecules react with substances in bodily fluids. The fluid "distributes itself into these various wells, or holes, and turns colors,"

JASON GROW

INVISIBLE ENGINEERS

A researcher recruits microscopic workers to manufacture high technology

NO. 35
NANOTECH WILL LIVE UP TO ITS POTENTIAL BY HARNESSING VIRUSES TO BUILD MACHINES.

ANGELA BELCHER, A MATERIALS CHEMIST AT THE MASSACHUSETTS Institute of Technology, is using nanotechnology to grow batteries. Out of viruses. Batteries that could last weeks or months and be thinner than a credit card. How did she get such an idea? Abalone shells.

"I'm really interested in how biology makes materials," Belcher says. "I've always been fascinated, for instance, with shells." Abalone seashells are made up mostly of calcium chloride—chalk—but because of how abalones mix that soft material with proteins at nanoscale sizes, the shells form a nearly unbreakable armor. "A lot of objects controlled at the nanoscale have unusual properties based on how they are made biologically," she says.

Working in her lab with materials scientists and bioengineers, Belcher started with a naturally occurring virus called the M13 bacteriophage and inserted genes that caused the virus to become a template for tiny, self-assembling wires. Some wires, made of cobalt oxide and gold, become the negative poles of the battery. Others, made of iron phosphate covered in carbon nanotubes, form the positive poles. The ultrathin wires, several nanometers in diameter, can be combined to form high-power electrodes for lithium-ion batteries like those used in many modern electronics. But Belcher's batteries can be engineered into any shape imaginable.

Belcher's wizardry has attracted attention from the highest levels of government. President Obama stopped by Belcher's lab for a demonstration. She gave him a miniature copy of the periodic table of elements. ("In case you're ever in a bind and need to calculate a molecular weight, here's a periodic table for your wallet," she told him.)

Belcher's batteries are at least a few years away from commercialization. They may show up first in a new generation of computerized credit cards. Or long-lasting lightweight batteries for gadgets like laptops or cellphones—or a lab on a chip. **MICHAEL ROSENWALD**

Belcher got her powerful idea from an abalone shell.

Despite the seeming chaos in his lab, "we're accustomed to making structures with nanometer-scale precision, and knowing where every atom is," says Whitesides (with product development scientist Patrick Beattie). "That's what we do for a living."

Whitesides explains. Think pregnancy test. A stamp that turns blue in one corner, for instance, might reveal one diagnosis; a pattern of other colors would diagnose another. The cost to produce diagnostic stamps is 10 cents each, and Whitesides hopes to make them even more cheaply. Just about any advanced cellphone with a camera could be programmed to process an image of the stamp.

"Whitesides is doing this brilliant work literally using paper," Bill Gates said two years ago. "And, you know, it's so cheap and it's so simple, it could actually get out and help patients in this deep way." Cheap and simple: Whitesides' plan exactly. He formed a nonprofit group, Diagnostics for All, to bring the technology to developing countries. The Bill & Melinda Gates Foundation is investing in the technology to measure liver function, a test needed to ensure powerful AIDS and tuberculosis drugs don't damage one of the body's most important organs. Right now, testing liver function in isolated parts of the world is generally too expensive or too logistically difficult, or both. Whitesides' stamp is also being developed to pinpoint the cause of fevers of unknown origin and identify infections. A prototype of the liver function stamp is being tested in the lab, and the early results, Whitesides says, are more than promising. The chip will begin to undergo field testing later this year.

Strolling across a stage in Boston—a rare home speaking event—Whitesides, in his fisherman's cap, lays out his vision for how the invention will be used, sometimes in lawless places: "My view of the health care worker of the future is not a doctor, but an 18-year-old, otherwise unemployed, who has two things. He has a backpack full of these tests, and a lancet to occasionally take a blood sample, and an AK-47. And these are the things that get him through his day."

It is a simple solution for a complicated situation, in a place far from Harvard, but working on the lab stamp is exactly where Whitesides wants to be. "What I want to do is solve problems," he says, back at his lab, holding his lab on a chip. "And if nano is the right way of solving the problem, I'll use that. If something else is the right way, I'll use that. I'm not a zealot for nanotechnology. I'm not actually a zealot for anything." Except, that is, for bringing meaning to things nobody can even see. His work could push the incredibly small architecture of nanotechnology into the architecture of everyday life.

MICHAEL ROSENWALD *wrote about the search for new influenza viruses for the January 2006 issue of* SMITHSONIAN.

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TECHNOLOGY

40 THINGS TO KNOW

Q&A

LAURIE ANDERSON HIGHER FIDELITY

FEW ARTISTS HAVE BEEN ON THE CUTTING *edge as long as Laurie Anderson, the 63-year-old musician, writer and painter who achieved wide fame in 1981 with "O Superman," a haunting song with robotic overtones that felt like a message from the future. Anderson—who was NASA's first (and, as yet, only) artist-in-residence, in 2002—mounted her new multimedia show* Delusion *this past February at the 2010 Cultural Olympiad in Vancouver. New York City-based writer Jamie Katz caught up with Anderson at her studio in Lower Manhattan.*

Can you imagine what we might be listening to in 2050?

Here's my prediction. We're now used to massively easy, highly compressed downloads of music, which have very low sound quality. You don't hear any of the life on an MP3. It's been squished beyond recognition. So I think people will want to hear beautiful sound again, and we'll be able to create amazing sound systems, either in people's homes or just everywhere. The stereo sound we rely on today—two boxes, left and right—is obviously a completely imprecise way to represent the way we hear. Our ears are much more complicated than that. I think there'll be really amazing acoustical spaces to listen to things in, and the sound replication will be hyper-real as well.

NO. 36

SOUND SYSTEMS THAT REPLICATE HOW WE HEAR WILL REPLACE THE STEREO.

What do you think great artists might be doing?

They'll have access to enormous libraries of sounds. Even now I'm able to access almost any sound that's ever been made. I do think the idea of musical chops—instrumental mastery—will still be around. Some of the more advanced experimental recordings are being done at ZKM, a famous German art and technical media center. I went there to visit and talk about sound. Walked into a huge room with hundreds of huge German microphones all over the place. And in the middle of this room was a guy wearing no clothes, shivering, playing the flute. I thought, what's going on? Microphones were inside his flute. He was without clothes because they were making too much noise. The sounds from a single note were astounding. It felt like your head was a barn, and a big wind was blowing in one ear and bouncing around the walls and then turning into a pitch and then into overtones and then slowly falling to the ground. It was fantastically beautiful.

Do you spend much time online?

I'm not on Facebook. I'm a miniaturist and a confessional writer, so it seems like it would be a natural form for me. I also like that the writing is meant to be conversational. But I like to work on things six different ways before I put them in a public situation, and the immediacy of the Web is not conducive to that. I also find it tyrannical. I'm not sure yet whether it encourages people to be more creative or to mold themselves more carefully to fit into the clean design of Facebook.

What qualities must an artist bring to her work regardless of the era, medium or technology?

I would just say one word—openness. And you could also say awareness. That's what I treasure in other people's work—when they create something that makes you go, "Whoa, I never saw that." In a way, what artists really do is extend your senses and your awareness of things. For me, the making of stuff—the creation of artworks—is not really to the point. The point is to experience things more intensely. I hear people commenting that culture is dying, but it's not true. People are making lots of fantastic things. You don't know about it, that's all. It's really hard to squash artists. They keep appearing and making things.

PERFECT PITCH

"The idea of musical chops—instrumental mastery—will still be around."

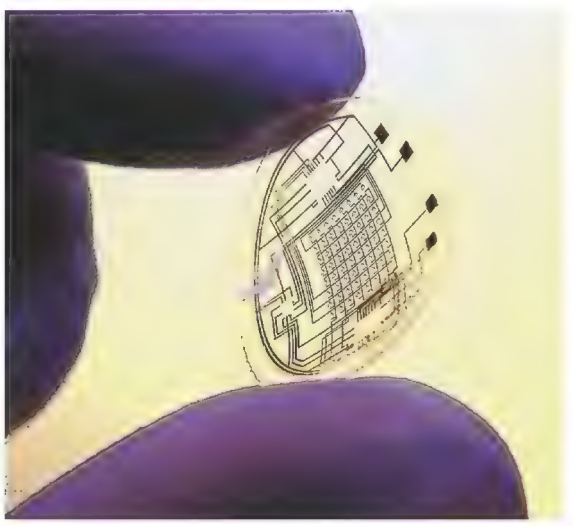
ANDREW MARKS / RETNA

POWER FROM THE PEOPLE

Energy harvested from our bodies will make possible mind-boggling gadgetry **BY MICHAEL BELFIORE**

SENSOR-STUDDED CLOTHING WORN BY A SOLDIER tracks his movements and vital signs. A disposable electrocardiogram machine the size of a Band-Aid monitors a heart patient. A cellphone is implanted in a tooth. Scientists and engineers are trying to develop such "embedded" devices: miniature electronics that plug people into computer and communication networks.

Consider contact lenses that function as computer screens. A University of Washington research team, led by electrical engineering professor Babak Parviz, has developed a prototype lens fitted with a tiny radio (for receiving data) and a light-emitting diode, or LED (for displaying data to its wearer). The technology has prompted comparisons to the computer readouts that flash in the eyes of the cyborg in the *Terminator* films.



Contact lenses that act as computer screens (above) face an obstacle: power.

In theory, the device converts electronic signals into ever-changing displays projected onto the contact lens and visible to the wearer, perhaps like a movie subtitle. If wirelessly connected to, say, a smartphone with voice-recognition software, a hearing-impaired person wearing such lenses might see a speaker's words translated into captions.

But engineers developing such embedded technologies face a big obstacle: power. The devices pack so much gadgetry into such tiny spaces that even the smallest batteries would be too bulky, never mind the inconvenience (and potential discomfort) of replacing them.

To solve the power shortage, the Defense Advanced Research Projects Agency (DARPA)—the U.S. Department of Defense agency behind technologies that led to the Internet and the Global Positioning System, among other things—launched an Energy Starved Electronics program in 2005 with MIT. Researchers there have a new idea for powering embedded electronics: "scavenging" energy from the human body.

Obviously, our bodies generate heat—thermal energy. They also produce vibrations when we move—kinetic energy. Both forms of energy can be converted into electricity. Anantha Chandrakasan, an MIT electrical engineering professor, who is working on the problem with a former student named Yogesh Ramadass, says the challenge is to harvest adequate amounts of power from the body and then efficiently direct it to the device that needs it.

In the case of harnessing vibrations, Chandrakasan and his colleagues use piezoelectric materials, which produce an electric current when subjected to mechanical pressure. For energy scavenging, ordinary vibrations caused by walking or even just nodding your head might stimulate a piezo material to generate electricity, which is then converted into the direct current (DC) used by electronics, stored in solid-state capacitors and discharged when needed. This entire apparatus fits on a chip no larger than a few square millimeters. Small embedded devices could be directly built onto the chip, or the chip could transmit energy wirelessly to nearby devices. The chip could also use thermoelectric materials, which produce an electric current when exposed to two different temperatures—such as body heat and the (usually) cooler air around us.

Powered by our own bodies, embedded technology promises not only to provide data wherever and whenever we need it but to transmit real-time data about ourselves. A jacket fitted with heating pads or the thermostats in our homes could adjust based upon our body temperature.

Steven Feiner, professor of computer science at Columbia University, says by 2050 embedded devices will allow us to immerse ourselves in a sea of not just visual data, but also computer-generated sounds and sensations. "However, I think that most people will instead have the system filter what they see," he says. "While on a walk in the woods, some folks might want to see overlaid species names." Then again, he adds, "others will just want to turn it all off."

NO. 37
ELECTRICITY TO DRIVE MINIATURE DEVICES WILL COME FROM YOUR SKIN.

MICHAEL BELFIORE's *book* The Department of Mad Scientists *is about* DARPA.

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TECHNOLOGY

40 THINGS TO KNOW

SHINING EXAMPLE

Solar technologies being pioneered in Spain show even greater promise for the United States BY RICHARD COVINGTON

AMID THE GREEN WHEAT FIELDS, OAK GROVES AND ANcient olive trees of Andalusia, a giant solar energy farm shimmers like a silver sea. Even under cloudy skies, the arrays of mirrors and massive towers sprawling over three square miles are an arresting sight.

Twenty miles west of Seville, the Solúcar solar farm, built by the company Abengoa, is part of Spain's push to produce more energy from renewable sources. The nation currently produces up to 3.65 gigawatts of power from the sun, second in the world after Germany. Those gigawatts make up about 3 percent of the country's power, the highest percentage in the world. (The United States generates less than 1 percent of its energy from the sun.) Spain's solar output is expected to rise in the next three years to seven gigawatts, enough to supply about ten million people—the combined population of Madrid and Barcelona—with electricity during the day.

The Solúcar farm is pioneering technologies that are being replicated in the United States, including concentrated solar power, or CSP. While traditional solar panels use photovoltaic cells to convert the sun's rays directly into electricity, CSP deploys huge banks of mirrors to focus solar radiation; the intense heat drives steam turbines, producing electricity in a process similar to the one used in coal- or oil-fired plants, but without the greenhouse gas emissions.

At the Solúcar site, two concrete towers—one about 50 stories tall, the other 35—collect light reflected by 1,879 enormous glass mirrors, each one 33 feet high and 40 feet wide.

The Solúcar facility's acres of heliostats, or mirrors, focus the sun's rays to create temperatures of 570 degrees, generating energy but not harmful emissions.

Atop the solar towers, concentrated sunlight (diffused through vapor and dust) boils water to drive steam turbines.

The mirrors, called heliostats, cover some 345 acres. They face south and are turned to follow the sun as it crosses the sky.

The smaller CSP tower began providing power in 2007, the larger one in May 2009. Together, they produce 31 megawatts. By 2013, when Solúcar is finished adding another tower plant and other installations, Abengoa expects the CSP facility to generate 300 megawatts, enough energy to power 220,000 households, or all of metropolitan Seville.

"These commercial tower plants are unique in the world," Valerio Fernández, Solúcar's operations manager, told me in his office overlooking the mirrored fields. (He was not counting a small, five-megawatt power tower operated in Lancaster, California, by the American company eSolar, or a demonstration tower the Spanish government runs in Almería.) "Today, however, they're on vacation," he added, with a shrug.

When it's raining or overcast—like the cool gray March day I visited—the solar installation shuts down. But photographs of the CSP site at its best are otherworldly: towers glowing with shafts of light, an effect caused by reflected sunlight passing through water vapor and dust in the air. Though you might think the south of Spain is an ideal solar energy site, Fernández said the company expects bad weather to reduce or halt energy production around 80 days a year, generally between November and March.

"If we are seeking to make solar power more efficient, there are better places than Seville," Fernández told me. He gestured to a wall map of the world with shaded bands representing solar energy potential: Andalusia was tan, the Mojave Desert of California and Nevada brown, and the Sahara darker still.

"The Mojave has about 30 percent higher solar radiation than we have here, so installing the same plants there will reduce the cost of electricity by 30 percent," he said. Efficiency is even higher for the scorching Sahara, where Abengoa and Desertec, a European consortium, aim to build solar facilities that will deliver power to Europe through cables beneath the Mediterranean.

NO. 38
U.S. ENERGY WILL INCREASINGLY DEPEND ON AN OLD-FASHIONED TECHNOLOGY: MIRRORS.

Fernández hefted a three-inch-wide piece of steel pipe off a bookshelf and handed it to me. It was from a tube in which water is converted to steam atop a CSP tower, and it had been painted black. "The blacker they are," he explained, "the better they absorb radiation."

The heliostats concentrate solar radiation so effectively that temperatures on the surface of the receiver tubes could potentially reach 3,600 degrees Fahrenheit, about one-third of the sun's surface temperature. "Unfortunately, the steel would melt and the receiver would break down," Fernández said dryly. Ceramic materials could perhaps withstand such heat, he went on, but they haven't yet been developed and tested. So on bright days plant operators adjust the heliostats to limit the sunlight directed at the towers and maintain the tem-

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DENIS DOYLE / GETTY IMAGES; PP. 116-117 MICHAEL MELFORD / NATIONAL GEOGRAPHIC SOCIETY / CORBIS

A separate power plant uses trough-shaped mirrors to collect the sun's rays and heat a synthetic oil to create steam.

perature around 570 degrees—plenty hot to make steam out of water, which boils at 212 degrees.

As Fernández drove me around Solúcar's campus, we stopped at the construction site for Solnova 1, the first of five planned CSP facilities here to use so-called parabolic trough technology. Solnova 1 will deploy mirrors shaped like shallow troughs, each several hundred yards long and about two yards high, in parallel rows like ranks of immense shiny ribbons. At the focal point of each mirror will run a transparent tube filled with a synthetic oil. The mirrors will direct sunlight to the tubes, and the heated oil will be used to boil water for turbine-driving steam.

Leaving Solnova 1, I caught sight of a vast array of photovoltaic panels. Although the panels supply around three megawatts of electricity—enough to power 2,200 households—Solúcar has not emphasized photovoltaics. "Photovoltaics are not leading to a technology that can store energy except in batteries," Fernández said. That is too costly.

A more efficient storage system is on display at Solúcar's TES (for Thermal Energy Storage) facility, which uses concentrated solar power to heat huge containers of molten salts, chiefly sodium and potassium nitrates, to some 570 degrees. The salts retain heat for up to six hours, meaning that it can be released after the sun goes down. This storage method could solve, at least partially, solar energy's toughest challenge: providing power at night.

Spain's booming solar capacity has depended on hefty government support. (CSP plants, for example, cost about twice as much to build and operate as conventional coal-fired plants.) The Spanish government's subsidy to solar energy providers—among the world's most generous—is running to more than €1.5 billion, or almost $1.9 billion, a year.

In the United States, federal and state governments are providing smaller financial incentives to individuals, solar power firms and utilities. Parabolic trough facilities in California and Nevada already generate more than 370 megawatts, and Abengoa is planning a 282-megawatt plant using similar technology near Phoenix, said Reese Tisdale, solar research director for Emerging Energy Research in Cambridge, Massachusetts. New parabolic trough, photovoltaic and CSP plants are proposed in California, Nevada, New Mexico, Colorado, North Carolina and Florida.

One massive solar farm, using towers and heliostats and promising to generate 392 megawatts of power, is slated for construction in, yes, the Mojave Desert in Southern California, if it passes state and federal environmental reviews.

"If you want to be optimistic," Tisdale said, "there could be as much as eight gigawatts supplied by solar power plants [in the United States] by 2025." That would be enough to power a U.S. city of six million (Americans use more electricity than Spaniards) and save 37,260 barrels of oil or 11,000 tons of coal a day.

RICHARD COVINGTON *writes from his home near Paris.*

MARKEL REDONDO / BLOOMBERG / GETTY IMAGES

TECHNOLOGY

40 THINGS TO KNOW

Q&A

VINTON CERF GOOGLE'S VIEW

IN THE LATE 1960S, WHEN VINTON CERF *was a UCLA graduate student in computer science, he helped design ARPAnet, a predecessor of the Internet. He's now a vice president of engineering at Google, the search engine giant that owns YouTube and is extending its reach to mobile devices, publishing and journalism. He spoke with associate Web editor Brian Wolly about how the Web will evolve.*

Ten or more years from now, how will we communicate with one another?

It's very possible we will be more continuously connected. Even today, people have Bluetooth things hanging in their ears. There's no reason they won't have a video camera located in a buttonhole, maybe even a video projector. And there'll be no need to carry a laptop or [computer] notebook, because any flat surface with reasonable visibility could become a display.

Virtually any appliance is going to be online. Appliances will talk to each other and to the power-generation system. Our appliances will pay attention to our preferences.

One of the real hard questions is, how will we keep up with all [the new applications]? Maybe our [computer] systems will be more aware of what our daily lives are like, what things we want to accomplish in the course of a day, and if that could be built into the software, maybe some of this stuff won't even require our explicit interaction.

NO. 39
YOUR FRIDGE IS JUST ONE OF THE MANY APPLIANCES THAT WILL BE TALKING TO YOU.

How will today's young people benefit?

How old is YouTube? Four or five years, right? And it has become an enormous phenomenon. At Google we see 23 hours of video being uploaded to YouTube per minute, and I'm sure that will increase over time. So trying to project what tools will be available over the next 40 years is really daunting.

Henry Kissinger once told me he was very concerned about the Internet's impact on people's ability to absorb information in a concentrated way, because we've become accustomed to looking up something, getting a snippet and being satisfied with that—as opposed to reading through and considering a weighty tome that goes into great depth.

I am reminded of the apocryphal story of someone complaining about the invention of writing because it would cause us to stop remembering things. Nonetheless, writing turned out to be pretty important. [Kissinger's] complaint may or may not be a materially serious issue.

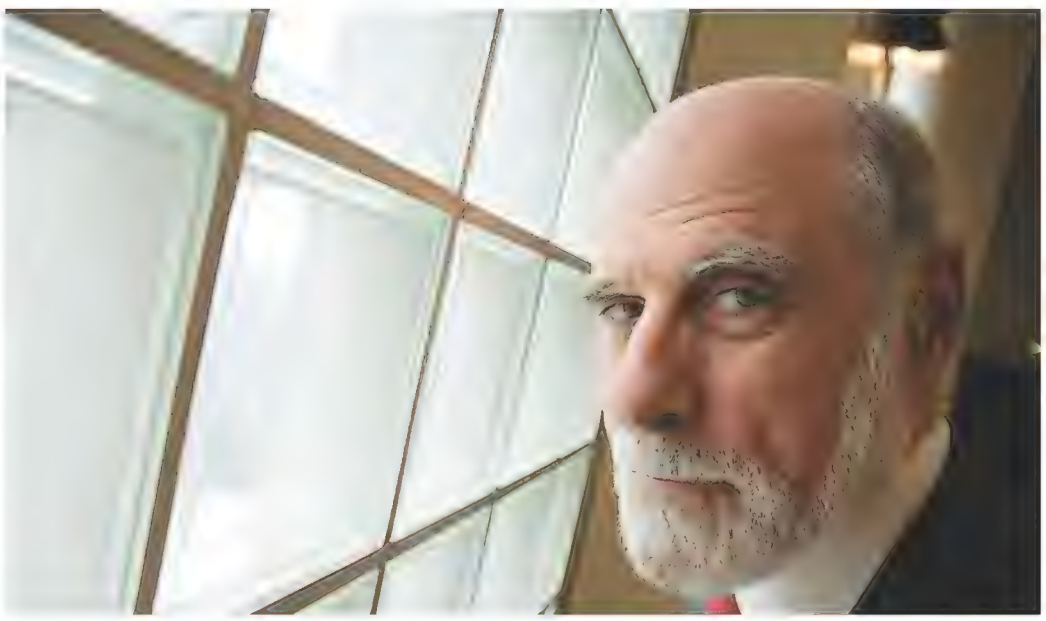
I'm not sure we know enough at this stage to justify a conclusion about the benefits of the kind of interactive, fast exchanges that take place in multi-user games [on the Web]. Are we solving problems, learning how to multitask? Is that a good thing? I don't know. It's a little bit like television. When it arrived there were many expectations that it would improve education and everything else. But what we discovered is there's a finite amount of quality in the universe, and when there are more channels it has to be cut up into smaller and smaller amounts until finally, every channel delivers close to zero quality, and that's where we are today, with a few exceptions.

One thing we know for sure is that the Web is a collaborative medium unlike any we've ever had before. We see people working together, playing together, interacting in social settings using these media. We hope that will emerge as the new tool for education.

The problem is—and this is true of books and every other medium—we don't know whether the information we find [on the Web] is accurate or not. We don't necessarily know what its provenance is. So we have to teach people how to assess what they've found. That's a skill, a critical-thinking capacity, which is important no matter what the medium. It's just more dramatic in the World Wide Web, where there's so much juxtaposition of the good stuff and not-so-good stuff and flat-out-wrong stuff or deliberate misinformation or plain ignorance.

CRITICAL MIND

The Internet pioneer sees a need to separate Web fact from Web misinformation.



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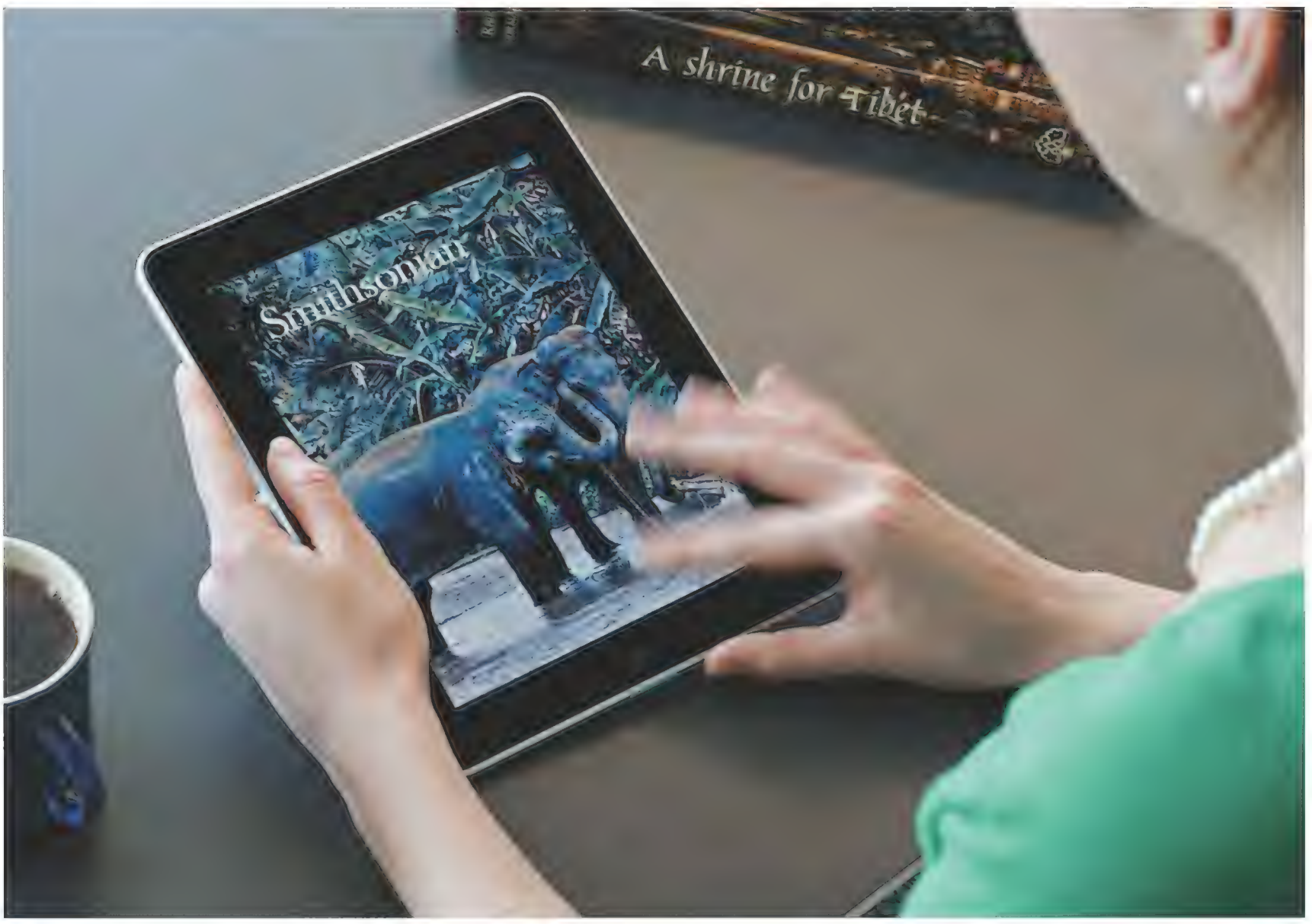
TECHNOLOGY

40 THINGS TO KNOW

FROM PRINT TO PIXEL

As digital screens proliferate, people are reading in a whole new way

BY KEVIN KELLY



AMERICA WAS FOUNDED ON THE WRITTEN WORD. Its roots spring from documents—the Constitution, the Declaration of Independence and, indirectly, the Bible. The country's success depended on high levels of literacy, freedom of the press, allegiance to the rule of law (found in books) and a common language across a continent. American prosperity and liberty grew out of a culture of reading and writing.

But reading and writing, like all technologies, are dynamic. In ancient times, authors often dictated their books. Dictation sounded like an uninterrupted series of letters, so scribes wrote down the letters in one long continuous string, justastheyoccurinspeech. Text was written without spaces between words until the 11th century. This continuous script made books hard to read, so only a few people were accomplished at reading them aloud to others. Being able to read silently to yourself was considered an amazing talent. Writing was an even rarer skill. In 15th-century Europe only one in 20 adult males could write.

After Gutenberg's printing press came along around 1440, mass-produced books changed the way people read and wrote. The technology of printing expanded the number of words available (from about 50,000 words in Old English to a million today). More word choices enlarged what could be communicated. More media choices broadened what was written about. Authors did not have to compose scholarly tomes but could "waste" inexpensive books on heart-rending love stories (the romance novel was invented in 1740), or publish memoirs even if they were not kings. People could

Interactivity (above: the iPad, with *Smithsonian*'s first cover, April 1970) nurtures action over contemplation, Kelly says.

BRENDAN MCCABE / *SMITHSONIAN*

write tracts to oppose the prevailing consensus, and with cheap printing those unorthodox ideas could gain enough influence to topple a king, or a pope. In time, the power of authors birthed the idea of authority and bred a culture of expertise. Perfection was achieved "by the book." Laws were compiled into official tomes, contracts were written down and nothing was valid unless put into words. Painting, music, architecture, dance were all important, but the heartbeat of Western culture was the turning pages of a book. By 1910 three-quarters of the towns in America with more than 2,500 residents had a public library. We became a people of the book.

Today some 4.5 billion digital screens illuminate our lives. Words have migrated from wood pulp to pixels on computers, phones, laptops, game consoles, televisions, billboards and tablets. Letters are no longer fixed in black ink on paper, but flitter on a glass surface in a rainbow of colors as fast as our eyes can blink. Screens fill our pockets, briefcases, dashboards, living room walls and the sides of buildings. They sit in front of us when we work—regardless of what we do. We are now people of the screen. And of course, these newly ubiquitous screens have changed how we read and write.

The first screens that overtook culture, several decades ago—the big, fat, warm tubes of television—reduced the time we spent reading to such an extent that it seemed as if reading and writing were over. Educators, intellectuals, politicians and parents worried deeply that the TV generation would be unable to write. But the interconnected cool, thin displays of the second wave of screens launched an epidemic of writing that continues to swell. The amount of time people spend reading has almost tripled since 1980. By 2008 more than a trillion pages were added to the World Wide Web, and that total grows by several billion a day. Each of these pages was written by somebody. Right now ordinary citizens compose 1.5 million blog posts per day. Using their thumbs instead of pens, young people in college or at work around the world collectively write 12 billion quips per day from their phones. More screens continue to swell the volume of reading and writing.

NO. 40
READING WILL BE MORE ATHLETIC. IT WILL SEEM WEIRD TO READ WITHOUT MOVING YOUR BODY.

But it is not book reading. Or newspaper reading. It is screen reading. Screens are always on, and, unlike with books we never stop staring at them. This new platform is very visual, and it is gradually merging words with moving images: words zip around, they float over images, serving as footnotes or annotations, linking to other words or images. You might think of this new medium as books we watch, or television we read. Screens are also intensely data-driven. Pixels encourage numeracy and produce rivers of numbers flowing into databases. Visualizing data is a new art, and reading charts a new literacy. Screen culture demands fluency in all

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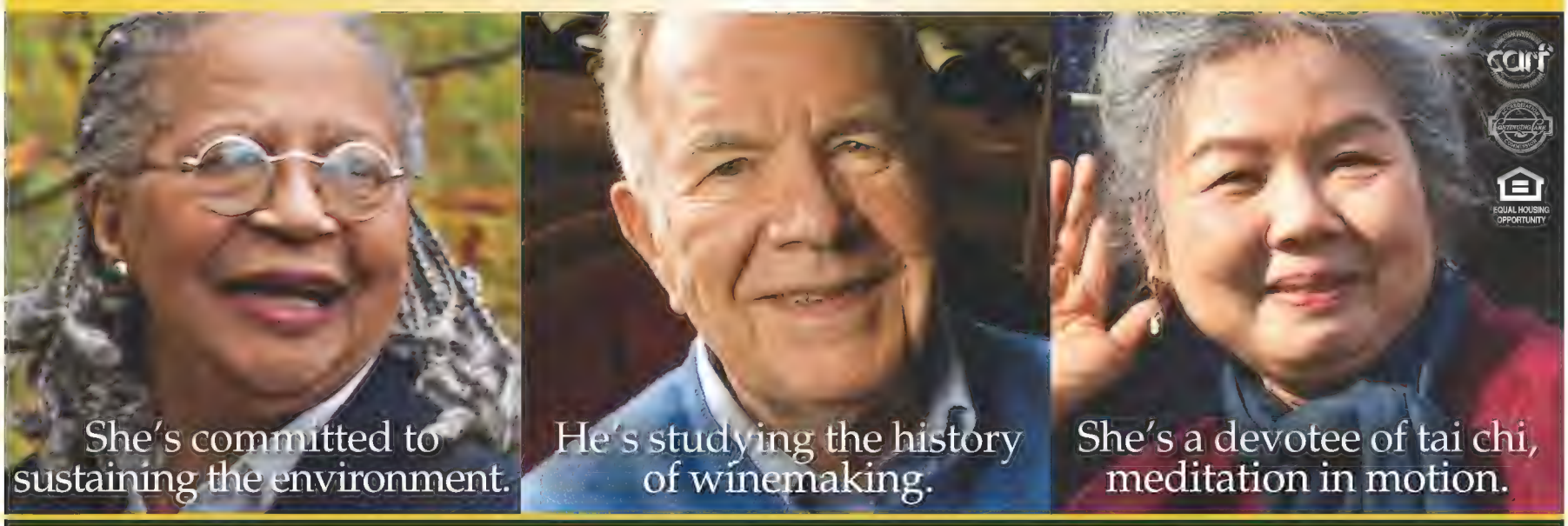
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Unlike books, the author says, screens are always on, and we never stop staring at them. (A father reads to his daughter.)

kinds of symbols, not just letters.

And it demands more than our eyes. The most physically active we may get while reading a book is to flip the pages or dog-ear a corner. But screens engage our bodies. Touch screens respond to the ceaseless caress of our fingers. Sensors in game consoles such as the Nintendo Wii track our hands and arms. We interact with what we see. Soon enough, screens will follow our eyes to perceive where we gaze. A screen will know what we are paying attention to and for how long. In the futuristic movie *Minority Report* (2002), the character played by Tom Cruise stands in front of a wraparound screen and hunts through vast archives of information with the gestures of a symphony conductor. Reading becomes almost athletic. Just as it seemed weird five centuries ago to see someone read silently, in the future it will seem weird to read without moving your body.

Books were good at developing a contemplative mind. Screens encourage more utilitarian thinking. A new idea or unfamiliar fact will provoke a reflex to *do* something: to research the

GARY TRAMONTINA / THE NEW YORK TIMES / REDUX

term, to query your screen "friends" for their opinions, to find alternative views, to create a bookmark, to interact with or tweet the thing rather than simply contemplate it. Book reading strengthened our analytical skills, encouraging us to pursue an observation all the way down to the footnote. Screen reading encourages rapid pattern-making, associating this idea with another, equipping us to deal with the thousands of new thoughts expressed every day. The screen rewards, and nurtures, thinking in real time. We review a movie while we watch it, we come up with an obscure fact in the middle of an argument, we read the owner's manual of a gadget we spy in a store before we purchase it rather than after we get home and discover that it can't do what we need it to do.

Screens provoke action instead of persuasion. Propaganda is less effective in a world of screens, because while misinformation travels fast, corrections do, too. On a screen it is often easier to correct a falsehood than to tell one in the first place; Wikipedia works so well because it removes an error in a single click. In books we find a revealed truth; on the screen we assemble our own truth from pieces. On networked

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Eyeglasses will apply an informational layer to reality. If you look at an object through them, the object's essential data will appear in overlay text.

screens everything is linked to everything else. The status of a new creation is determined not by the rating given to it by critics but by the degree to which it is linked to the rest of the world. A person, artifact or fact does not "exist" until it is linked.

A screen can reveal the inner nature of things. Waving the camera eye of a smartphone over the bar code of a manufactured product reveals its price, origins and even relevant comments by other owners. It is as if the screen displays the object's intangible essence. A popular kid's toy (Webkinz) instills stuffed animals with a virtual character that is "hidden" inside; a screen enables children to play with this inner character online in a virtual world.

As portable screens become more powerful, lighter and larger, they will be used to view more of this inner world. Hold an electronic tablet up as you walk along a street, and it will show an annotated overlay of the real street ahead—where the clean restrooms are, which stores sell your favorite items, where your friends are hanging out. Computer chips are becoming so small, and screens so thin and cheap, that in the next 40 years semitransparent eyeglasses will apply an informational layer to reality. If you pick up an object while peering through these spectacles, the object's (or place's) essential information will appear in overlay text. In this way screens will enable us to "read" everything, not just text. Last year alone,

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Products from shoes to cans of soup will contain a sliver of dim intelligence in the form of transistors. We will interact with that information through screens.

five quintillion (10 to the power of 18) transistors were embedded into objects other than computers. Very soon most manufactured items, from shoes to cans of soup, will contain a small sliver of dim intelligence, and screens will be the tool we use to interact with this transistorized information.

More important, our screens will also watch us. They will be our mirrors, the wells into which we look to find out about ourselves. Not to see our face, but our status. Already millions of people use pocketable screens to input their location, what they eat, how much they weigh, their mood, their sleep patterns and what they see. A few pioneers have begun lifelogging: recording every single detail, conversation, picture and activity. A screen both records and displays this database of activities. The result of this constant self-tracking is an impeccable "memory" of their lives and an unexpectedly objective and quantifiable view of themselves, one that no book can provide. The screen becomes part of our identity.

We live on screens of all sizes—from the IMAX to the iPhone. In the near future we will never be far from one. Screens will be the first place we'll look for answers, for friends, for news, for meaning, for our sense of who we are and who we can be.

KEVIN KELLY'S *book* What Technology Wants *will be published in October.*

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I am an 88 year old woman with multiple health problems. After seeing the ad for the Exerciser 2000 Elite® I ordered it and use it daily. I can tell it has improved circulation in my legs and by doing that it has helped my balance and walking problems. To those of you that think that you can't do regular exercise anymore, try this piece of equipment and you will be amazed how much better you will feel. —*Mildred F.*

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CONTINUED FROM PAGE 96

Because of movies, which satisfy so many people's need for a visual effect and aural effect combined, theater is going to go increasingly toward things that only theater can do. In the new poetry, I see a fascinating confidence in switching viewpoints very quickly, in mid-sentence practically. So there's a speeding up of changing viewpoints and expressions that comes from technology speeding us up and the fact that you can keep several screens open at a time and divide your attention. The narratives are getting faster and are having more interruptions because we can tolerate interruption.

Genealogical research is causing more people to embrace a multiracial heritage. How will this affect literature?

It cuts down on stereotyping and the fear of the other, because we all are the other or the other is us. The assumptions of the mainstream change. A mainstream novel of the early '70s or so would contain the dilemmas of, say, a household in Connecticut. Everything that had to do with country clubs or the tensions at a cocktail party was assumed to be the mainstream. That left a burden of explanation for any writer who was not of the mainstream. So a Jewish-American writer had to go into great details to explain Seder, or an African-American writer had to explain—somehow in the context of their story—how they did their hair. Now that we are more and more identifying ourselves as multiracial, these elements of other cultures are becoming better known. That will change the nature of the mainstream, and that is quite a tidal wave.

You once asked, "Why can't we find the universal in our differences?" Is literature getting there?

Absolutely. That's one of the great shining lights of the future. I think as we become more multicultural and able to look at each corner of the world, the more at ease we are with our differences. And we are going to be more comfortable reading something about experiences which are, on the surface, very different from ours. Yet we'll still feel confident that we can access the common humanity.

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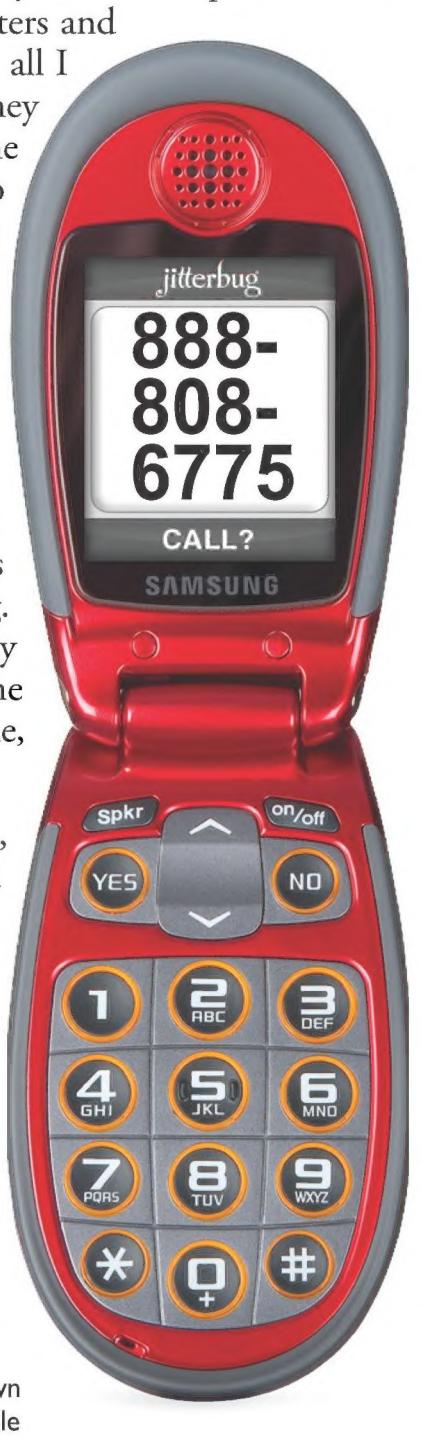

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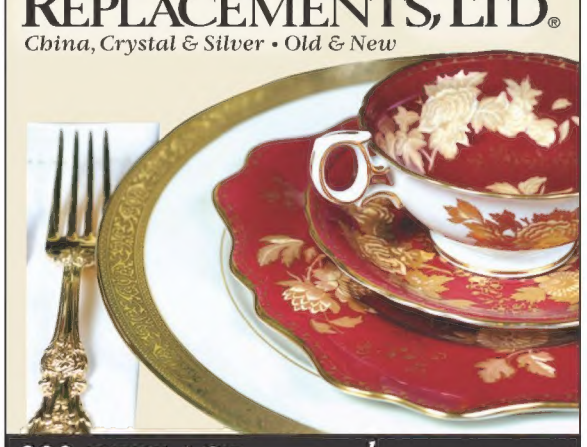

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CONTINUED FROM PAGE 104

Islamic world and its culture. It is a key turning point in that relationship. It was received that way in many parts of the Islamic world, even by people who are skeptical. I heard a conversation in Cairo between two people—it happened in front of me—where somebody said, "Yes, but does he mean what he says?" And somebody else said, "But he said it! He actually said those words."

What about in Europe, where there's now a movement to ban the veil in France and to ban minarets in Switzerland?

They are bound to realize very soon that Islam is in Europe. The whole idea that Islam is in the Muslim world and we can somehow control this relationship and keep it static is wrong. This idea of "them" and "us" is just going out of fashion. It's not working anymore. In the 19th century, the Muslim world was a remote place, a place of fantasy. The cultural links came through the translation of *One Thousand and One Nights*. What happened, from the 19th century to the 21st, is that these walls of mystification have been lifted. It's no longer the land of the monsters and the djinn. And it's a very difficult thing to come to terms with.

There are huge geopolitical issues to work out. Meanwhile, how can the average person bridge these cultures?

By simply thinking of people as people like them, by visiting museums and looking at work that comes from there and trying to understand it. Making that effort and wanting to find out is part of the duty of each one of us. Most Islamic art is not even signed; most is anonymous. The concept of a masterpiece is not the same as in the West. The concept of the artist is not the same. This is not art that was produced to be hung on the walls. The scale is much smaller, which calls for an intimate relationship. Basically, it is calling you to come close and look, to accept that it is different and try to understand that even though it's small, it might have something to say. Maybe it's whispering. Maybe you need to get closer.

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Abraham Lincoln once said, "Let us have faith that right makes might." Do you have that kind of faith? Or do you think that idealistic principles are outdated and impossible to achieve?

Read Richard W. Wetherill's book *RIGHT IS MIGHT* to discover why *right* really is *might*, and how the natural laws of the universe make it so.

Richard W. Wetherill
1906-1989

During his lifetime, Wetherill was often described as a person who was scores of years ahead of his time. Now former members of his research and study group think that his day has finally come. Increasingly, more and more people understand that to succeed they must be rational and honest.

In 1929, Wetherill identified a ***natural law*** controlling people's personal and interpersonal behavior. ***The law states that people are required to think, say, and do what is right in order to get a right result.*** It further states that when people have personal problems or trouble, something is wrong about their thinking, conversation, and behavior.

In his book Wetherill explains the outcome that results from attempted violation or disregard for nature's behavioral law. As with all natural laws, this law is also self-enforcing. Persons who deviate from what is right install in the recesses of their minds the wrong thinking that was used to justify such behavior.

While Wetherill's book *RIGHT IS MIGHT* was written in 1950, its contents are as applicable in 2010 as they were sixty years ago—perhaps even more so—and because Wetherill could not find a publisher willing to go out on a limb for honesty and right action in 1950, the manuscript was simply filed.

After his death in 1989, the manuscript was found among his papers, and it was carefully edited to delete some dated material, but the principles of right behavior that he put into words are ageless. They are all preserved.

RIGHT IS MIGHT tells the reader how honesty and rightness are achieved in a person's private and public life. It also describes the exciting developments in the lives of persons who had applied the formula for successful living

A reader might ask, "What did they do?"

Following Wetherill's suggestions they recognized the challenges of life and met life head on; squared themselves with their consciences; did what could be done to improve conditions; and made sure that every personal decision was completely honest.

People who do that do not fear the future. They know that the key to every virtue is honesty, so they wage an intentional campaign of unwavering honesty.

Adopting that dynamic formula for success benefits everybody on earth. It will benefit posterity. Before it benefits others, the person who adopts it is the first to benefit. Rational, honest thoughts and behavior is a formula not open to abuse. Nobody can cause trouble for others or for himself by using it. Not using that formula causes trouble for everybody.

The last paragraph of *RIGHT IS MIGHT* reminds us, ***"It is helpful to recognize that what is wrong in life is based on emotional unreality and is temporary. What is right in life is part of the reality that unfailingly endures, establishing the principle that RIGHT IS MIGHT."***

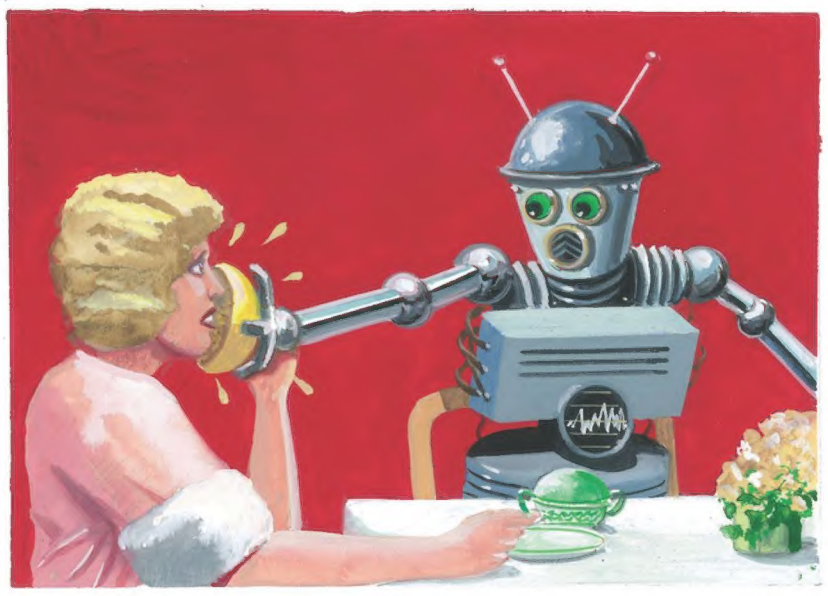
Visit our Website www.alphapub.com where essays and books (including Right Is Might) describe changes called for by whoever or whatever created natural laws. Read, download, and/or print the material free! Press a button to hear site pages read aloud, except for the texts of the seven books.

This message is from a self-financed, nonprofit group of former students of the late Richard W. Wetherill. By May of 2010 our Website had over 50,000 American and worldwide visitors. We invite your help to direct others to alphapub.com to learn how to find the ***examined*** *life that is well worth living.*

Married, With Glitches

Survey finds human-robot unions undone by technical difficulties **BY BRUCE McCALL**

"My forecast is that around 2050, the state of Massachusetts will be the first jurisdiction to legalize marriages with robots."
—Artificial intelligence researcher David Levy
Maastricht University



From *The American Journal of Annulment and Divorce*
June 2053

UNDERLYING CAUSES OF HUMAN-ROBOT MARITAL DISCORD

In the first major study undertaken since the passage of the Automaton Marriage Act of 2050, questionnaires distributed to 125 recently divorced couples have yielded the following findings:

PART I

Humans tire of their robot mates almost three times faster than robots tire of humans.

1. The key reasons cited by humans for dissatisfaction with robots are:

- "That infernal humming."
- Stench of overheated or burning electrical wires, especially during lovemaking.
- Robots can't go in the water, limiting family vacation options.
- Simple maintenance regimen among robots (software upgrades, frequent oil changes) spawns corrosive resentment in flesh-and-blood partners.
- Robots refuse to perform household chores, citing "degrading leftover stereotypes dating back to crude 2010-era robot clichés."

2. Robots disenchanted with human spouses list three primary causes:

- Human minds comparatively slow and sluggish, with limited memory and frequent lapses; need to use pen/pencil even for simple $E=mc^2$ calculations.
- The human need to eat and sleep creates "hopeless" scheduling incompatibilities.
- Snoring.

PART II

Our surveys reveal that extramarital infidelity is the "tipping point" for the deterioration of human-robot relationships.

1. As noted elsewhere in roboliterature (see "Russian Robot Wives Date Cyclotrons," *National Enquirer*, March 2047), a notorious flaw of robots' artificial intelligence technology is an underdeveloped moral sense. Over 75 percent of human-robot marital spats involve rampant robot promiscuity.

2. Survey Q #36: "Is 'monogamy' absent from the robot word-recognition program?": Yes: 98.6 percent. Ought to Be: 1.32 percent. Don't Know: .08 percent.

PART III

Post-divorce life for humans is generally more fraught than for their robot ex-partners, according to statistics compiled by Massachusetts' Suddenly-Single Outreach Program:

1. Almost 95 percent of divorced robots patronized a downtown club, appliance store or singles bar within two hours of the final decree. (Figure for divorced humans: 4 percent.)

2. Survey Q #59: "Plan to keep in touch with human former in-laws?": No responses.

PART IV

Can the robot-human divorce epidemic be curbed? It's too soon to tell. But helpful clues have surfaced:

1. A panel of ex-NASA pastors concludes that a joint prenuptial reading of any up-to-date robot technical manual can nip many ill-advised person-machine romances in the bud.

2. Given the sobering fact that at least half of all human-robot marriages occur within 48 hours and 15 square miles of major electronics expos, it would appear that the glamorous swirl typical of such venues raises unreal expectations for both human and robot. Better for initial "hookups" to take place in more emotionally neutral settings; e.g., a lab or biomechanics conferences not held in Las Vegas.

BRUCE MCCALL *is a writer and artist in New York City.*

BRUCE MCCALL